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CONSTRUCTION SPECIAL

Build a 40M Rig from scratch K8IQY's 2N2/40

Journal of the Northern California QRP Club

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From the Editor

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Wow, another year has come and gone, and we have the final issue for 1998. This one is special, because I did not do most of the work in this issue. Paul Harden layed out the fantastic article by Jim Kortge, and did the wonderful illustrations for it. The reason? I was absolutely tied up with the kitting of the NorCal 20 kits which shipped in late January. I want to publicly thank Paul Harden, NA5N, who saved me on the winter issue. It would not have been out until late March if not for Paul's efforts.

The NorCal 20 as mentioned above, shipped in late Jan. and were we ever glad to see it finally get out the door. But the wait was worth it, as Dave Fifield, the designer, and the whole NC20 team of Dave Meacham, Mike Gipe, Gary Surrency, Doug Hauff, Jerry Parker, Brad Mitchell, Rich Fisher, Gary Diana, Bill Jones, Dave Adams, Jim Cates, George Dobbs, Jim Smith, Lee Johnson, Dave Gauding, and I apologize for leaving anyone out, all worked their fingers to the bone to assure a high quality kit that worked right out of the box. This radio kit has 350 parts, we built 5 rounds of prototypes, spent several thousand dollars on R&D, and even tested every board on a test bed at the board house. The VFO took 4 members, Dave F., Gary, Mike and Dave M. 5 weeks of testing to insure a stable VFO with minimum drift.

We hope that the members enjoy our efforts. Kitting of the 3rd world kits will begin in March, after a 30 day period of rest for me, and also to allow any problems to surface before we mail the kits.

Included in this issue are plans to build the 2N2/40 rig that was the winner of the NorCal 2N2222 design contest held last year. Jim Kortge's design is wonderful. I urge all of you who have ever wanted to build a rig from scratch to do so. Use Paul Harden's wonderful drawings. You can't go wrong. When you finish, I think you will be amazed at the quality of the

radio that you have just built.

As with the NC20 project, the 2N2/40 project was not rushed. Jim, Preston Douglas, and Paul worked many, many hours to assure all of us a quality article that will fast become one of the classics.

There is also a flyer in this issue that advertises the Atlanticon QRP Event to be held on March 27th in conjunction with the Timoneum Hamfest. It is being sponsored entirely by the NJ QRP Club. There is NO charge to attend the QRP Forum, which features 7 World Class QRP Speakers, and NO charge for the wonderful compendium that goes to the attendees.

I want to congratulate George Heron and the rest of the NJ QRP Club crew for doing this forum in the true spirit of ham radio and QRP. They are giving back to QRP and helping others, which is what it is all about. We now have major QRP Events on both coasts, and both of them are very similar. World Class speakers, no charge for admission, evening open houses, no host meals at a local restaurant, free compendium, building contests, and most of all, fun.

The NJ QRP Club also has a neat new kit out, the Jersey Fireball 40. The best thing is that the price is only $10 delivered to your door!! The information is also on the flyer and it is a blast to build. Proceeds from the kit are used to support Atlanticon.

If you are anywhere near Atlanticon, I sincerely urge you to attend. It will be a wonderful time, and one that you won't ever forget. QRPers are the best people in ham radio, and they sure know how to have the most fun.

Also, don't forget that the annual NorCal QRP Club Contest, QRP to the Field will be held again on the last Saturday in April. The theme for this year's contest is the same as last year, Run For the Border. Be sure and check out Joe Gervais announcement at the end of the results of last year's contest. By the way, the New England QRP Club started the "To the Field" QRP events. They held one in the fall. I contacted Jim Fitton and urged him to have another one in the spring. He declined, but suggested that NorCal sponsor one in the spring, which we did and have since that time. Paul Harden, NA5N was the first to suggest a theme for the contest, and he started something that has certainly increased the participation. Thanks to Paul and Jim for their support.

I will be attending the Ft. Smith, Arkansas hamfest to give a talk on QRP on March 13th. Hope to see many of you in the area there. This is the second year for a QRP forum there, and Jay Bromely, W5JAY is doing a lot of work getting it organized.

The next issue of QRPp will be an exciting one. Dave Fifield will have an article on the NorCal 20, The NJ QRP Club has another project to announce, plus there will be a full construction article on the Fireball 40.

The back issues for 1998 will be available March 1. The price is going up to $20 per year for the 98 issues, as we are using a wire binding, and costs are going up. Postage and handling have also increased. See the inside back cover for ordering information.

Thanks again to all of you who participated in the NorCal 20 project. I was amazed at your patience with the whole process. You are to be commended. We only had 2 complaints out of all of the orders, an astounding fact. We tried to do the best job possible, but that takes time. Certain things happened that caused delays, parts procurement, delays in the production of the boards, etc. all part of the game. But the end result is worth it. Enjoy QRP. 72, Doug, KI6DS

K8IQY's "2N2/40" Forty Meter CW Transceiver

by Jim Kortge, K8IQY
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Introduction.

The beginning of the 2N2/40 came about when Wayne Burdick, N6KR, proposed his "post apocalyptic" design contest for Dayton 1998. The premise of the contest was that "no matter what happens to us or the planet, you'll still be able to find them (2N2222's) in huge quantities." It is as Wayne termed it, "The cockroach of the transistor world." The contest challenge was to design a system, capable of transmitting and receiving, using only 2N2222 transistors as the active device, and using no more than 22 of them. A corollary to the constraints was that only other "cockroach parts" could be used, such as 1N914 diodes, but not three terminal regulators, PNP transistors, ICs, or anything of that ilk!

My interest in accepting this challenge was to design and build a transceiver from the ground up, something that I had always wanted to do, but never set aside the time to accomplish. Here was the "golden opportunity", if one ever existed. Along with this, I had been experimenting with MicroSim's PSPICE off and on for several months, but didn't feel that I had a very good understanding of its capabilities, nor how to use it very well. Combining the two elements, design and computer circuit simulation, would provide a valuable learning experience, provide a robust design assuming I was successful, and maximize the "fun" that could be derived from such a project. With those thoughts in mind, it was time to get serious and design and build a rig.

Design Criteria

At the onset, I struggled with some basic questions: "What will I design and build?" "Should it be on CW, and if so, what band?" "Maybe it ought to be something for SSB, then I could use it for bicycle mobile, if it works well." However, reality set in, and the recognition that I had never done this before, so keeping it relatively simple was most appropriate. Forty meters seemed like a good band for a CW rig, as I didn't have a QRP rig for that band, and kept missing out on the Fox Hunts. Sure, I would listen to the gang on my FT990, but the desire to put it on the air wasn't there; it just didn't fit my notion of what that contest is all about.

Another self imposed constraint was to not just lift circuits or designs from various books, but attempt to design the rig from the knowledge gained over many years of reading, listening, experimenting, observing, and operating. That sounds like re-inventing the wheel a bit, and to some degree it is, but it also frees the mind to consider other approaches. Some of that thinking shows up in the rig, and I'll discuss it later in detail.

So 40 meters got the nod for the band, and CW was the mode selected, mostly because of ease of design and construction. A number of the other issues that one would consider resolving at the beginning of a project were left, because I didn't know how difficult it might be to implement various sections sections of the rig, and how many of the 22 transistors would get used in each section.

However, there were some desired basic features in the rig that did not impact the transistor count. These included an r.f. gain control, and a variable bandwidth filter. Features that did depend on transistor count included having an r.f. amplifier to make up for input filter losses, power output of 1-2 watts, and the ability to drive a speaker. All of these were "desirable", but would be reconsidered if all the transistors got used up elsewhere.

Another criterion was to build the rig as small as practical, so that it could go into a QRP-size cabinet. However, at the onset, I had no idea how large or small that might be. The building approach would be to start out with a fairly large piece of single-sided PC board material and begin building in the middle of it. As the design and construction progressed, the circuitry would be built outward, toward the edges. If all of the room wasn't needed when the rig was finished, then a quick trip to the band saw would remove the unused and unneeded board material.

The anticipated approach to use was to design a particular section, build the computer model for that design, optimize the computer model, build and test the section, and finally, compare the test results with those predicted by the modeling. This approach had been used once before on a two band SSB rig that was started for bicycle mobile use, but never finished. For much of that rig, I didn't know enough about modeling to build the models of the ICs that were being used. However, the approach had been used for the antenna T/R switch and the receiver input filter, and it was amazing how closely the actual circuit matched the frequency response predicted by the modeling. What wasn't known was whether this approach would work for a complete rig, and how many design iterations would be required before getting it to work satisfactorily.

As it turned out, the approach worked very well. There were a few iterations on one or two circuits, but for the most part, circuits were built with the component values shown by the modeling to be optimal. The total time to do the design and construction was considerable. I started around the middle of November 1997, a short time after the contest was announced and some 2N2222 transistors had been acquired. It wasn't until nearly the end of April 1998 that the job was done. A good portion of that time was spent doing the actual construction. My building speed could best be described "slow and precise", spending far longer on thinking about and visualizing how a section should be done than most builders would. However, the finished product is quite nice; almost "art like" in its appearance. The first part of May 1998 was spent feverishly getting the rig into a case and assembling the documentation package so that I could take it to Dayton.

Construction Background.

Over the past five or so years, many small projects have been built using a method that I was told years ago is called "Manhattan Style Construction". It's also called "Paddyboard" in some circles. The "Manhattan" name I believe comes from the fact that the little pads and parts that are used look a lot like a city in miniature, when they're all on the substrate. The substrate is usually a piece of single sided PC board material, copper side up. The pads are glued to the surface of the substrate, copper side up, and become the junction points for the circuitry that requires support. The copper ground plane is available for soldering all component leads that go to ground.

Editors Note: *This special construction feature is intended to encourage anyone to build a QRP rig from scratch. The following construction practices were written by Jim Kortge, K8IQY, and illustrated by Paul Harden, NA5N, as a step-by-step guide on the techniques required to properly build the 2N2 rig, or most any homebrew project from scratch.*

1. Construction Practices & Techniques

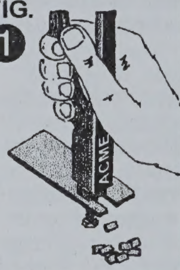
The mounting pads - are made of single-sided copper clad PC material, cut into small pieces and glued to the main ground, or substrate board (a 5x7 inch pieice of solid copper clad for the 2N2/40).

My favorite method of making the small pads is through the use of an ADEL nibbling tool. This is a tool designed for cutting thin sheet metal, but can handle 1/16 inch thick PC board material quite well. The resulting pads that are produced by this tool are about 3/32 inch wide by 1/4 inch in length. (See **Fig. 1**) While that might seem a bit small to most, there is ample room on one pad to solder the ends of 3 or 4 components.

Other alternatives for making the pads is cutting the copper clad PC material into small strips in a mitre box or bench vise as illustrated in **Fig. 2**. The strips can then be cut with wire cutters into the small pads.

Making the "Pads"

FIG. 1



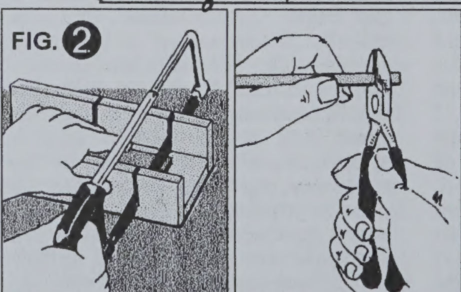
The primary way of making the pads is using a nibbling tool to cut small pieces out of single-sided copper clad board. This also ensures "pads" of uniform size and shape, and fairly fast to perform.

Nibbling tools are available from many tool suppliers and at many Radio Shack stores for about $15.

The copper clad board with holes on 0.1" spacing can also be used. Cutting along the holes with wire cutters tends to break them off 2-holes at a time for a 0.1x0.2 pad with an "octagon" look, shown in **Fig. 3**. File or sand the rougher cuts of this method if desired. A round hole punch from Harbor Freight has also been used by many QRPers for making round pads 3/16 to 1/4" dia.

Making the "Pads"

FIG. 2

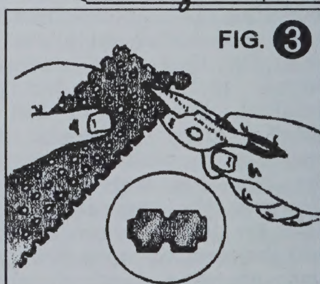


Copper clad strips for the pads can be cut with a sharp saw and mitre box.

Pads are then cut to desired length with wire cutters or tin snips.

Making the "Pads"

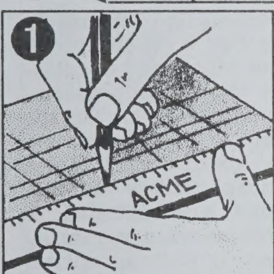
FIG. 3



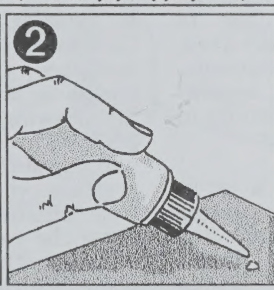
Copper clad with the pre-punched holes on 0.1 inch centers makes good pads also.

Mounting the Pads.
I use common Cyanoacrylate adhesives, (DURO Super Glue) although any of the available, thin adhesives of this type should work. My method for attaching a pad is to hold it in place and put a very small drop against the bottom edge of the pad and the substrate. The thin glue will wick under the pad and attach it in about 5 seconds. Others have tried this method and have had problems and prefer to apply a drop of glue to the board, then mount the pad. The secret is to make sure the surface of the substrate is very clean, and devoid of any sensitizing films, grease, or other contaminants. I scrub my board material with soap and water and a piece of 3M Scotch Bright pad until the copper is shiny. It is then wiped with lacquer thinner to remove any remaining contaminants. When this method is successful, removing a glued down pad requires twisting it off with a pair of pliers as illustrated in **Fig. 4**. Each pad is also wiped across a piece of 400 grit wet and dry sandpaper several times on the copper side before gluing to the substrate. This cleans it and makes soldering to it very easy. Cleaning with a mild solvent or alcohol and brush can also be used to "clean up" the pads before soldering as shown in **Fig. 5**.

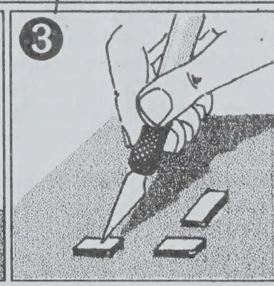
The "Pad" or "Manhattan" Technique



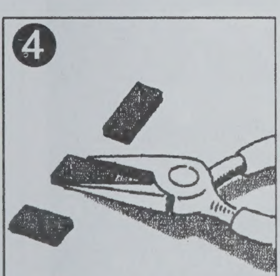
Draw footprints of each section and guidelines with pencil on the copper clad board. Planning ahead is important!



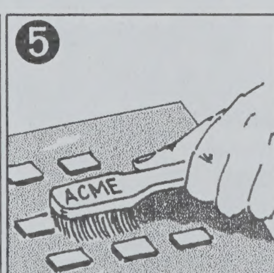
Apply drop of Super Glue or other adhesive to the main board where pad is to be placed. (Glue 1 or 2 at a time!)



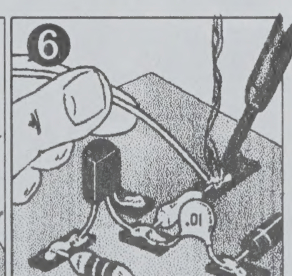
Drop pads in place over glue and position with exacto knife or other sharp object.



Super glue affixes the pads quite well! To remove or reposition a pad, snap-off by a twist with needle-nose pliers.



Board and pads can be cleaned with brush and alcohol, mild solvent or water. Excess glue may have to scraped off.



Solder the components to the proper pads by following the detailed assembly drawings that follow.

Mounting the Components.
Mounting the various parts to the pads is mostly what could be called a "common sense" approach. I let the "geometry of the environment" guide how a part will be mounted, since there is no standard or accepted way of soldering a part into the circuit.

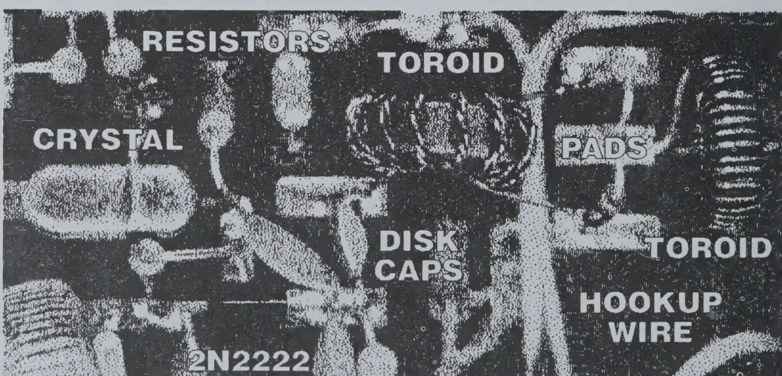
Resistors are generally mounted vertically, for two reasons. First, I think they take up less space that way, allowing one to build more compactly. Second, the higher end also makes a convenient test point; that's why a small loop is put in the higher end lead. It is nice to install resistors with the color codes running from the higher end to the lower end, for easier readability, just in case a mistake is made in building. Occasionally, resistors should be mounted horizontally, either to better span the distances involved, or maybe fit under another component. That's done in several places in the 2N2/40, especially in the audio amplifier section.

Capacitors. There is not a lot to discuss regarding capacitor mounting, since the predominant type used has radial leads. When capacitors are mounted, I try to orient them so that their value can still be read. With components going to ground, one lead needs to be approximately 1/16 inch longer than the other to be soldered vertically to the substrate (ground plane). For leads that are soldered to the substrate, I bend the lead at a right angle at the appropriate length, and leave about 3/16 inch of length for soldering. Leads that will attach to a pad are bent at a right angle also, and have about 3/32 inch of length for soldering.

Transistor and diode leads should be bent about 1/4 to 3/8 inch away from the body. One additional comment is that component leads are prepared one at a time to ensure they fit to their respective pads.

Toroidal coils seem to be troublesome for many. There are detailed winding steps on the next page.

A typical mounting scheme is illustrated in Fig. 6 on the previous page, and of course, as illustrated in the step-by-step assembly drawings that follow. On the 2N2 drawings, special components, such as toroidal coils, crystals, varicap diodes, etc. are well illustrated and detailed to show the recommended mounting scheme. There is nothing critical about the parts placements in the following assembly drawings, should you decide to add your own "flair" or arrangement.



A small portion of Jim's 2N2/40 rig showing a few typical components mounted (soldered) onto the pads

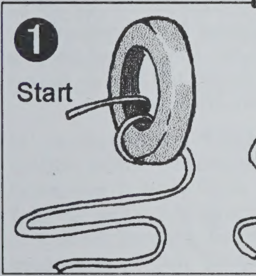
The 2N2 rig, like many QRP rigs today, use toroidal transformers and coils that you must wind yourself. Toroids are cheap, easy to wind, have relatively high-Q's, and "self shielding." Follow these step-by-step instructions, and you will have no problems. Each toroid in the 2N2 is illustrated in detail on the assembly drawing pages to make things easy.

Each time the wire passes through the ***inside*** *of the toroid, it is* ***one turn***. Thus, there are 2-turns in Fig. 1, 3 turns in Fig. 3, and 12 turns shown in Fig. 4.

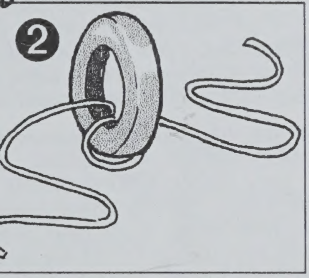
HINTS for Toroids:

- Estimate wire length needed by:
  For T37 - 0.6 inch per turn
  For T50 - 0.8 inch per turn
  Add 2-3 inches for leads, safety
- It doesn't matter which way you wind the toroid, but in the case of a transformer, ensure primary and secondary are wound in the same direction for proper phasing.
- Use #24-28 enamel covered *coil wire*, or as specified.
- PVC/mylar covered #24-#30 wire-wrap can also be used, although inductance may vary slightly over coil wire.

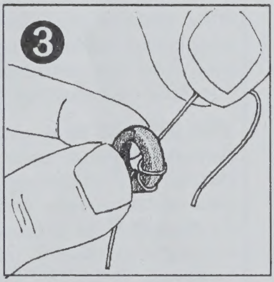
Winding Toroidal Coils



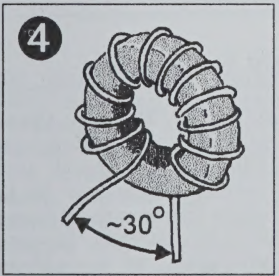
For about a dozen turns or less, start coil wire through toroid as shown, leaving 1-2 inches on start end.



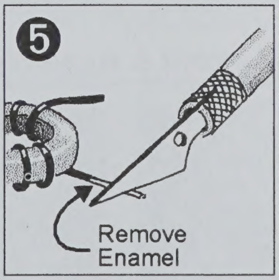
For 12 turns or more, start at half-way point of the coil wire, winding one-half first, then finish with the second half.



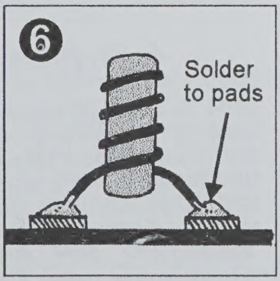
Hold toroid and starting turns with one hand, loop wire with the other, keeping the wire snug against the toroidal core.



When done, windings should be evenly spaced around toroidal core with a gap at the bottom. Trim leads to ½ in. long.



Scrape off enamel from lead ends with a knife. Tin with solder to ensure all coating is removed for a good connection.



Form leads and solder to the mounting pads, with toroid mounted vertically as shown. That's it!

3. 2N2/40 Specifications

RECEIVER

Narrow front end: 150 KHz bandwidth
Sensitivity: -122 dBm MDS (~0.2 uV)
Diode DBM first mixer
Very low noise
VFO: 100 KHz band coverage
  200 Hz maximum drift
  Linear varicap diode tuning
3 pole VBW crystal filter: 300-700 Hz
Push-pull audio output
  for speaker operation

TRANSMITTER

1.5 watts output using
  three 2N2222A's in parallel
Excellent r.f. stability
QSK keying
Meets FCC requirements for
  harmonic rejection (-36dBC)

Overall.

- 22 - 2N2222 transistors; four are 2N2222A metal case types
- All circuits modeled with MicroSim DesignLab or Electronics Workbench
- Built from "scratch" - Manhattan style construction
- 5 inch by 7 inch total footprint size
- Easily fits in many ready-made enclosures

Note from NA5N:
I had the pleasure of having Jim's 2N2/40 in my possession for some time for the purposes of performing lab tests, doing the illustrations contained herein, and making a few QSO's with it. I returned the rig and had the priviledge of working Jim a week later, with him using the 2N2/40, during the Zombie Shuffle *contest on Halloween.*

The 2N2/40 is a serious, high-performance QRP transceiver. *It has very good sensitivity (MDS <-120dBm), selectivity (300-700Hz variable IF filtering), very stable VFO (<200Hz drift first 5 minutes) and surprisingly good audio fidelity (and plenty of it). The "pads" form 3-8pF to ground, and being built over a solid ground from the copper clad board (and not using I.C.'s) lends itself for a very quiet receiver. You'll be impressed with the signal-to-noise ratio, inspite of the nominal -120dBm sensitivity.*

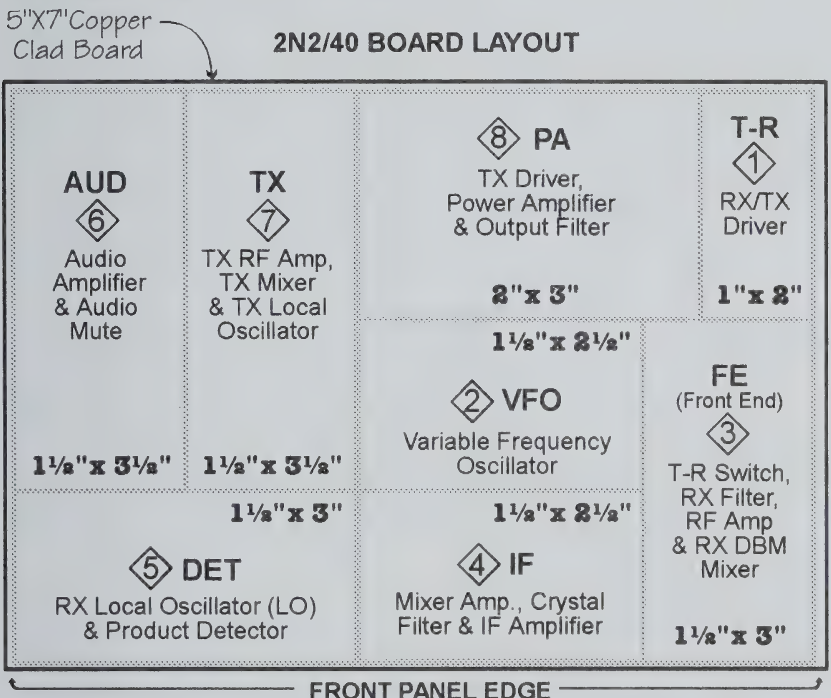
If you've ever wanted to build a QRP rig from scratch, I highly recommend building Jim's 2N2/40. It's a great performer, and why we worked so hard to document it to make it easy to build. I started building mine for the 1999 PacifiCon Building Contest!

4. Physical Layout & Assembly Sequence

Let's talk a bit about the layout used in the 2N2/40 and some of the thoughts and ideas that drove the design. We'll start with the RX/TX driver, only because it is very simple to let you develop your "technique" for making and mounting the pads. Then onto the VFO, since it's shared by both the receiver and transmitter. Then we will do the receiver, starting at the input, and ending at the audio amplifier. And finally, we'll tackle the transmitter. By the way, that's exactly the order in which the prototype rig was designed and built! As each section is highlighted, I'll also try to impart some insight into the various layouts that I've prepared, as an aid in reproducing the rig. While these layouts aren't exactly as the prototype rig was built, they are quite close. However, the size was opened up to 5 inches by 7 inches for this construction article so that

there is significantly more room, hopefully making it easier for the first time builder to construct. However, it can be built in a smaller area if you wish with a little forethought.

Layout. The overall layout for the 2N2/40 is shown below, based on using a 5"x7" copper clad board for the ground substrate. It closely follows how the prototype was built. Each block is numbered with the **sequence number (SEQ#)**, the suggested order for building each block, and the order for which this article is based. All drawings are based on the SEQ# for easy reference. Each block also shows the circuit functions it contains and the **footprint** ... the size of each block, which should be pencilled out on the board before mounting the pads to ensure proper fit.



The original T/R switch, input filter, r.f. amplifier, and double balanced mixer (usually called the receiver "front end", SEQ#3) were built along the right edge of the board, toward the VFO output transformer. When I got the DBM finished and mounted, (more on that later), it seemed like a good place to "turn the corner", so that was done. Before continuing on though, some testing of the existing circuitry seemed appropriate. Using my FT990 tuned to 4.915 MHz, the 2N2/40's intended i.f. frequency, I connected a test lead from the 990's antenna connector to the output of the receiver DBM. I connected a short antenna to the 2N2/40 input filter and powered it up. I could hear 40 meter signals, and they tuned with the VFO pot! Eureka.....it was working.

Building again started with the mixer amplifier (SEQ#4). Next came the crystal filter, the i.f.

amplifier, and the local oscillator for the product detector (SEQ#5) across the front panel edge of the board. This brought construction to a point near the left edge of the board. It was necessary to make another right turn. That allowed construction of the product detector (SEQ#5), mute switch, and audio amplifier (SEQ#6) along the left-hand edge, going from bottom to top.

At this point, the receiver portion was essentially done, and I spent about a week just listening to it, and marveling that it actually worked. In fact, it worked very well, far better than I had expected for just 2N2222 transistors. Spurred on by the success of the receiver, I was anxious to see how the transmitter might fare.

Looking over the remaining unpopulated areas of the substrate, it was pretty clear that the transmitter would need to be placed adjacent to the receiver mute switch and the audio amplifier. That also placed the transmit single balanced mixer reasonably close to the VFO, so that getting drive for it would be easy. I built the transmitter local oscillator, the single balanced mixer, and finally the cascode r.f. amplifier. At this point, there was no more room in the direction of the bottom of the substrate. Time to turn yet another corner, and start building toward the right.

However, I started to get a bit uneasy. The buildup of the transmitter r.f. driver (SEQ#7), the final amplifier output section, and the low pass filter (SEQ#8), was yet to be completed, and not much space was left. It was then that the decision was made to go to a "second story" if the rig was all to fit within the substrate footprint. The details at that point were unclear, but it was certain the final amplifier(s) were not going on the main board, but it was certain the final amplifier(s) were not going to fit on the main board, but somewhere else. After building the r.f. driver section, as expected, most of the space was used up.

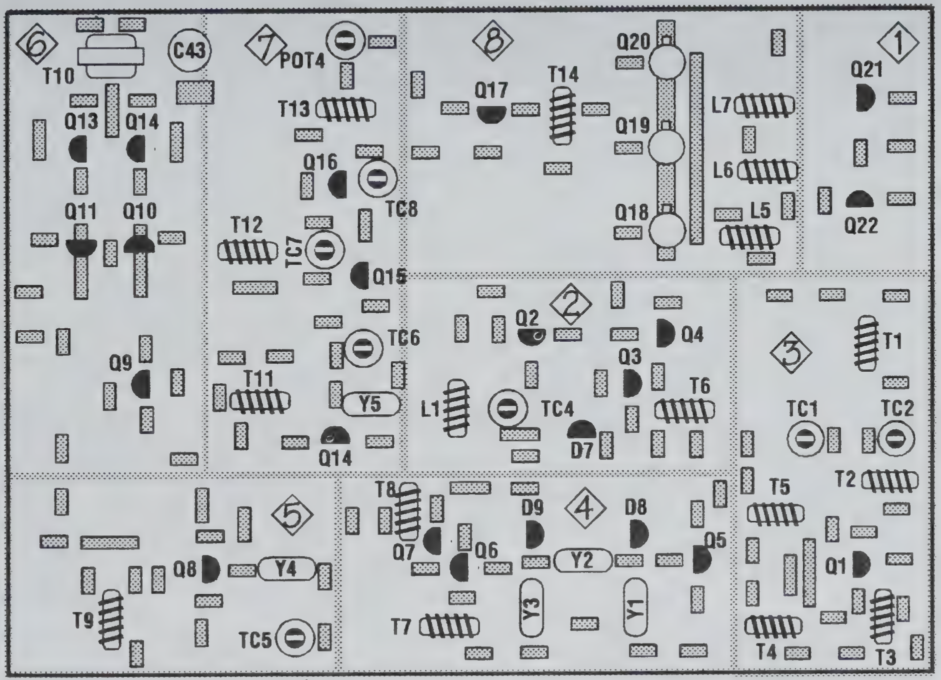
On the prototype rig, the three 2N2222A transistors used in the final amplifier are located on a 1¼ by 2½ inch piece of double sided PC board material. The transistors are on the top side, and the low pass filter components are on the bottom side. The whole affair is mounted on two 1 inch standoffs. Details of that construction are also shown in the Summer 1998 QRPp. As Paul Harden, NA5N pointed out, building the output final amplifier and low pass filter as a separate structure allows it to be replaced easily with another unit, maybe using a different bipolar or a MOSFET PA. The layout I've suggested, based on my second built 2N2/40, leaves ample room to put the three PA transistors and the output filter on the board. However, you could build the driver, PA, and LP filter on a separate 2x3 inch piece of material, just so you have the option of replacing it some time in the future with a different PA.

That completes the rig in terms of overall physical layout. Let's now move on to the various circuits and circuit sections and discuss them in more detail. Before leaving the layout diagram, one additional comment is appropriate. As a building aid on a 5 X 7 inch substrate, use a ruler and black marking pen with permanent ink and layout the lines as shown. When you build, don't put any component closer to a line than 1/8 inch. This will leave 1/4 inch "gutters" between each section which can be used for routing power and various signal lines. That approach worked really well on the second rig I built using the documentation from this article.

2N2 Board Layout and Pad Locations

Each assembly drawing illustrates in detail the location of every pad and every component in the 2N2/40 rig. However, the assembly drawings are *not drawn to exact scale* due to the "artistic latitude" required to clearly show every component. This drawing shows the EXACT location of the "pads." This is what should be used to layout the position of the pads ... always striving to keep within the footprint size for each section.

Major components only are shown for reference.



FRONT PANEL EDGE

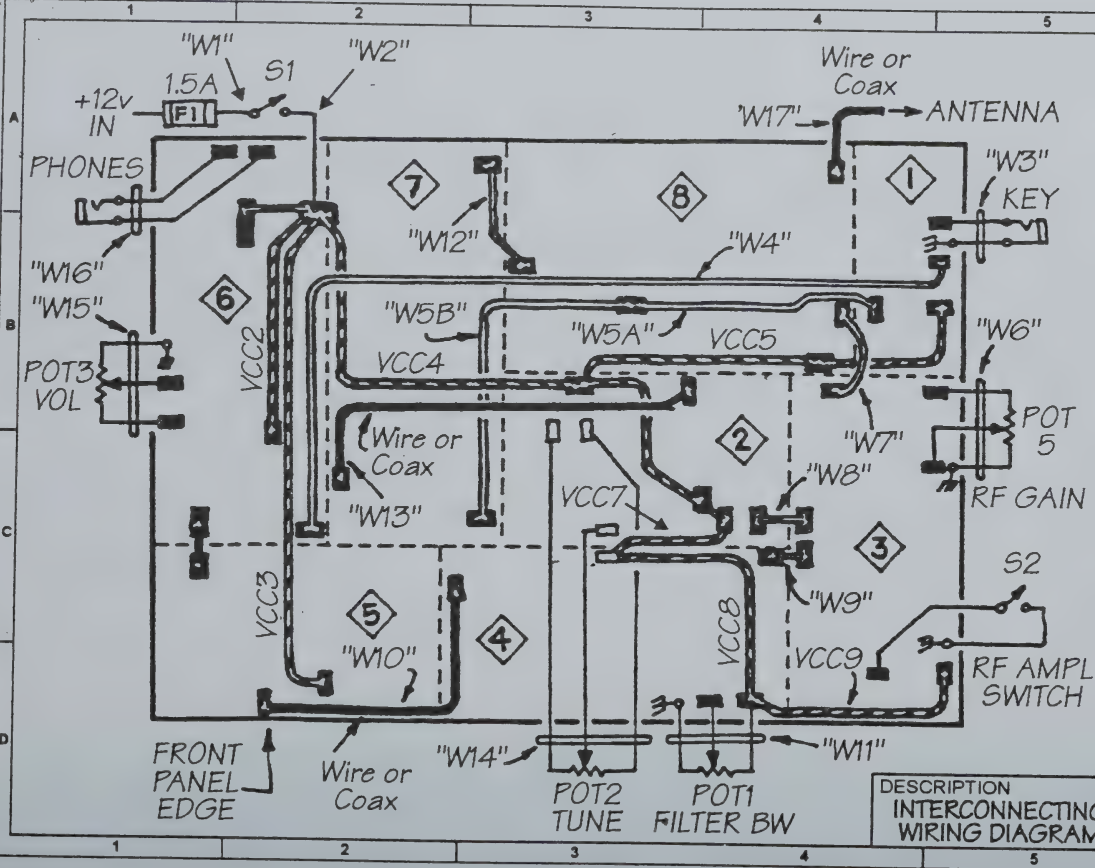
DESCRIPTION	2N2/40 QRP RIG
2N2 Board Layout & Location of "Pads"	Designed by Jim Kortge, K8IQY Drawn by Paul Harden, NA5N

2N2/40 Interconnecting Wiring

One of the advantages of Jim's design is very little wiring to perform except for the external components and the internal wiring for:

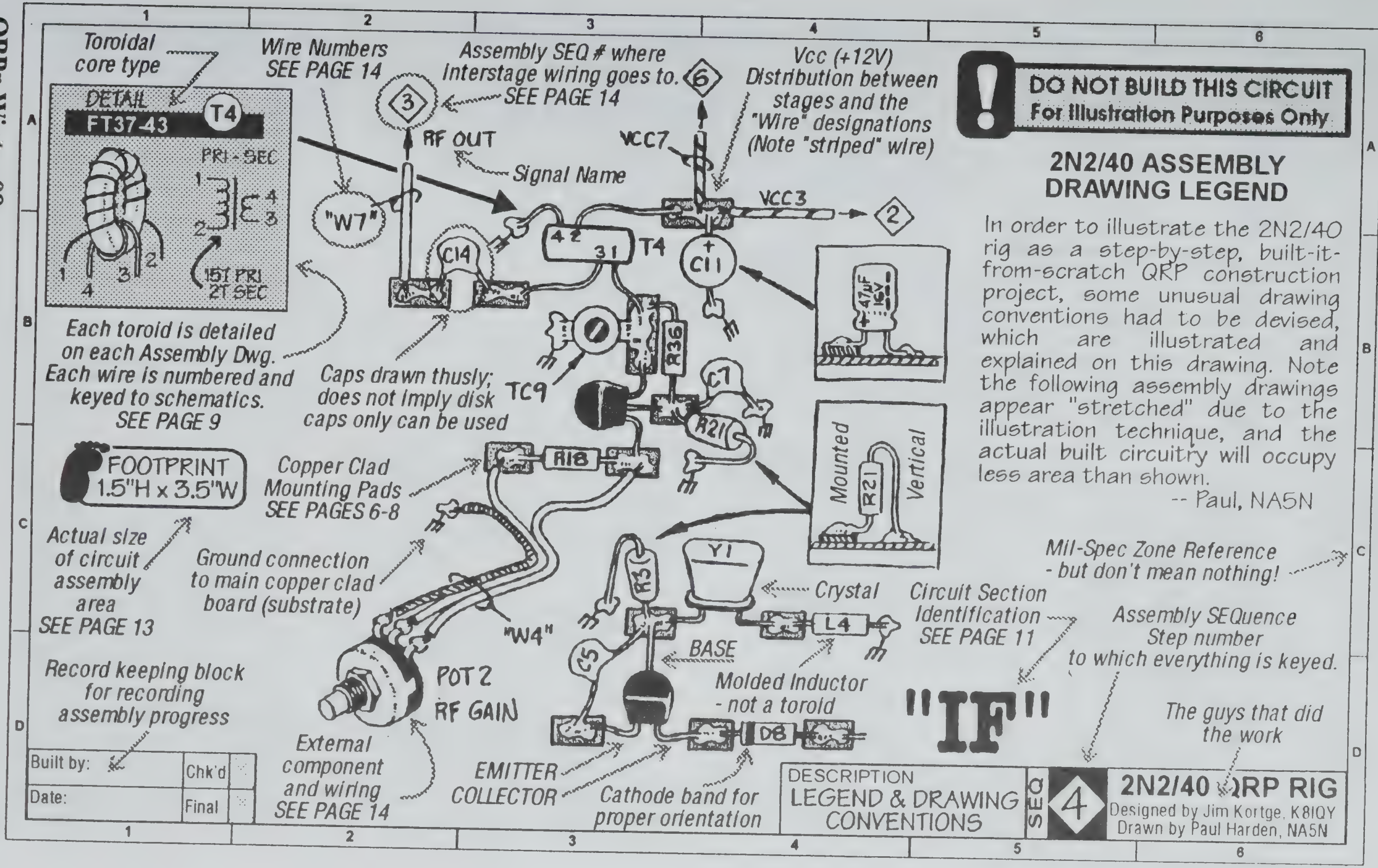
- +12v Vcc distribution
- RX and TX terms
- The VFO L.O. signals
- Connections between the sections.

Each wire is given a name (i.e. "W5," "VCC2), which is also shown on each assembly drawing. Use this drawing to check & verify that all section-to-section and external wiring is in place.



DESCRIPTION
INTERCONNECTING WIRING DIAGRAM

2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N


DO NOT BUILD THIS CIRCUIT
For Illustration Purposes Only
2N2/40 ASSEMBLY DRAWING LEGEND
In order to illustrate the 2N2/40 rig as a step-by-step, built-it-from-scratch QRP construction project, some unusual drawing conventions had to be devised, which are illustrated and explained on this drawing. Note the following assembly drawings appear "stretched" due to the illustration technique, and the actual built circuitry will occupy less area than shown.
-- Paul, NA5N
Toroidal core type
DETAIL
FT37-43
T4
PRI - SEC
151 PRI
2T SEC
Wire Numbers SEE PAGE 14
Assembly SEQ # where Interstage wiring goes to. SEE PAGE 14
RF OUT
Signal Name
"W7"
VCC7
VCC3
Vcc (+12V) Distribution between stages and the "Wire" designations (Note "striped" wire)
Each toroid is detailed on each Assembly Dwg. Each wire is numbered and keyed to schematics. SEE PAGE 9
Caps drawn thusly; does not imply disk caps only can be used
TC9
C14
C11
R36
C7
R21
R18
47uF 16V
Mounted Vertical
FOOTPRINT 1.5"H x 3.5"W
Copper Clad Mounting Pads SEE PAGES 6-8
Actual size of circuit assembly area SEE PAGE 13
Ground connection to main copper clad board (substrate)
"W4"
R3
Y1
Crystal
L4
C5
BASE
Molded Inductor - not a toroid
Circuit Section Identification SEE PAGE 11
Mil-Spec Zone Reference - but don't mean nothing!
Assembly SEQuence Step number to which everything is keyed.
POT 2 RF GAIN
Record keeping block for recording assembly progress
External component and wiring SEE PAGE 14
EMITTER
COLLECTOR
Cathode band for proper orientation
D8
"IF"
The guys that did the work
Built by:
Date:
Chk'd
Final
DESCRIPTION
LEGEND & DRAWING CONVENTIONS
SEQ
4
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

5. Circuit and Construction Details - Receiver

1 RX/TX Driver

Schematic	Assembly Dwg.
Sht. 4	SEQ. #1

Circuit Description.
The Rx/Tx driver switching circuit provides receiver and transmitter control. Transistor Q21 is normally "on" due to base drive from bias resistor R59 and R60. The port labeled "Rx" supplies current to audio muting transistor, Q9, via resistor R59 also. Since the collector of Q21 is near ground potential, (0.2 volts actually) transistor Q22 is turned "off", and no current is flowing out of its emitter.

When the "key line" is brought to ground via a straight key or keyer, the two transistors revert to their opposite states. Transistor Q21 is turned "off", and the current that was flowing through its collector--emitter junction is now flowing into the base of Q22, turning it "on". The emitter of Q22 now provides current to all of the transmitter sections that require current from the port labeled "Tx". These include the Tx LO, Tx Cascode Amplifier, and the Tx RF Driver stages.

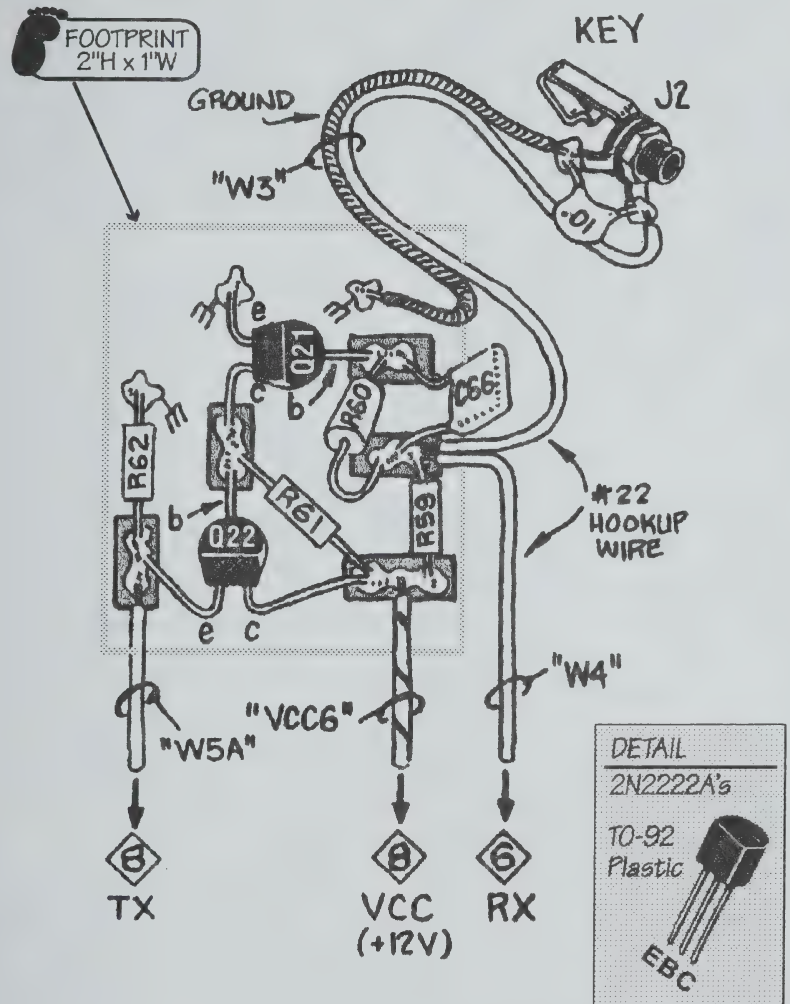
The voltage available at the Q22 emitter is the supply voltage, Vcc, minus its base-emitter forward drop, a value of approximately 0.7 volts, minus its collector-emitter saturation voltage, another 0.2 volts, or Vcc minus 0.9 volts. Had we been able to use a PNP transistor for Q22, the base-emitter drop would be eliminated, but then we wouldn't be using all 2N2222 transistors, as the contest rules required. Not having full supply voltage available to the transmit stages reduces their gain and output power by perhaps 10 percent, not enough to keep the design from working.

Assembly.
The RX/TX Driver is by far the easiest section in the whole rig to build. For that reason, it is the first to build, just to gain some experience mounting the pads and using the "Manhattan" technique to build the rig on this simple circuit block.

As you can see, this section is really simple - nothing critical in terms of layout, and lots of space to build it. Once completed, its port pads for terms RX and TX will be wired to the corresponding port pads in the receiver and transmitter. These switching terms will be wired to the other sections, as you build them, using hookup wire. Refer to the Interconnecting Wiring Diagram on page 14.

- Term RX is wire run "W4"
- Term TX is wire run "W5"

Testing.
For testing, you can add the external components with leads long enough that they will be appropriate when the rig is assembled in a case. With power applied, it should be in the receive mode, that is, RX=+11v, TX=0V. In the transmit "key-down" mode, RX=0v and TX=+11v. The real testing of this circuit, however, need not be performed until the 2N2/40 construction is completed.



NOTES:

1. Assembly drawings are not drawn to exact scale. Illustration technique makes layout appear larger than actually required.
2. Actual size of layout is shown by the "Footprint" dimensions.
3. Wiring for terms TX and VCC will be installed when SEQ8 is built; term RX will be installed when SEQ6 section is built.

"T-R"

Built by:	Chk'd	SECTION RX-TX DRIVERS (T-R Switching)	SEQ 1	2N2/40 QRP RIG Designed by Jim Kortge, K8IQY Drawn by Paul Harden, NA5N
Date:	Final			

2 Varicap Tuned VFO

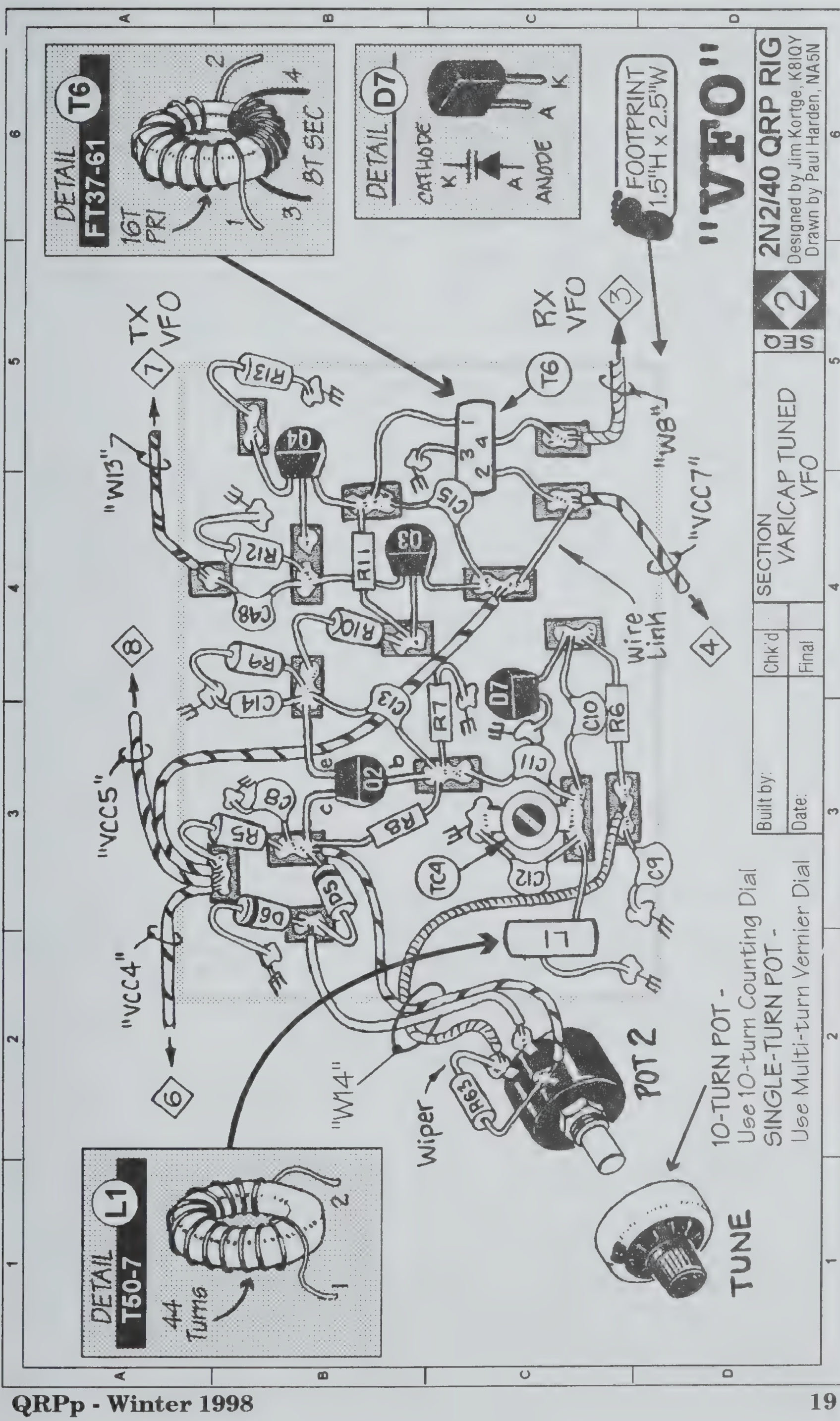
Schematic	Assembly Dwg.
Sht. 1	SEQ. #2

Circuit Description.
The VFO (variable frequency oscillator) is a classic Colpitts design, using a MVAM109 voltage variable capacitance diode for the tuning. It tunes from nominally 2.085 to 2.185 MHz, 100 KHz of band coverage. Trimmer TC4 is used to set the lower frequency limit, and TC3, if included, sets the upper frequency. Some adjustment of the turns on inductor L1 may be required to get the correct frequency range, with the values shown.

Important features include the main inductor, L1, which is wound on a T50-7 powered iron core. With the 44 turns required on this core, the inductance should come in around 8.5uH. Type 7 cores have the best temperature characteristics of any of the commonly available cores. What frequency drift occurs is downward in frequency as the temperature increases. To compensate for this drift, a negative temperature coefficient capacitor is employed, C12a, which moves the frequency upward with increasing temperature. Polystyrene capacitor C12a, in conjunction with C12b (NPO type) provides the correct amount of compensation to keep the frequency stable with changing temperatures. The combination of Zener diode D5 and power diode D6 provide a total of 6.9 volts from the 13.8 volt supply. Keeping the collector voltage low (~7 volts) on transistor Q2 and its components reduces heat dissipation, also helping VFO stability. All of the capacitors in the VFO are NPO types except for C12a and C13 and C14. C13 and C14 are 5% tolerance polyester capacitors, which are quite stable with temperature. VFO drift from a cold start is under 200 Hz. The VFO tuning linearity is improved by swinging the varicap diode, D7, between 6.9 and 0.7 volts, avoiding the most non-linear portion of the capacitance curve, which occurs near 0 volts. Resistor R63, also helps linearize the VFO tuning by effectively changing the linear potentiometer, POT2, into a non-linear unit which approximately matches the tuning diode capacitance versus voltage curve.

Transistor Q3 serves as a buffer, keeping load changes from affecting Q2, the oscillator. Output from the emitter of Q3 is used to drive the transmitter single balanced mixer. The VFO signal is further amplified by transistor Q4, to provide the +10 dBm drive level (0.7 volts rms) required by the receiver double balanced mixer. Signal output is transformer--coupled to the receiver mixer from the secondary winding of T6. The primary winding is 16 turns on a FT37-61 core for 14 to 15 uH of inductance, depending how it is wound. It is tuned by capacitor C15 to provide the required driving power, and to reduce harmonic content output. The VFO also has low phase noise, as shown in the spectral display measured by NA5N on page 20.

Assembly.
The VFO layout is shown in Assembly Drawing **SEQ#2**. As you can see, the construction starts on the left at L1, and flows to the right, where the main output, the secondary of T6, is positioned to be close to the receiver DBM in section SEQ#3. The output going to the transmitter single balanced mixer, Tx VFO on SEQ#7, will be routed through shielded cable (RG-174, etc.) to reduce radiation into surrounding circuitry. There is some latitude for constructing the VFO in terms of alternate part locations. It doesn't have to be built as shown. Just try to keep the overall size within the footprint, so that you have enough room for the other sections.



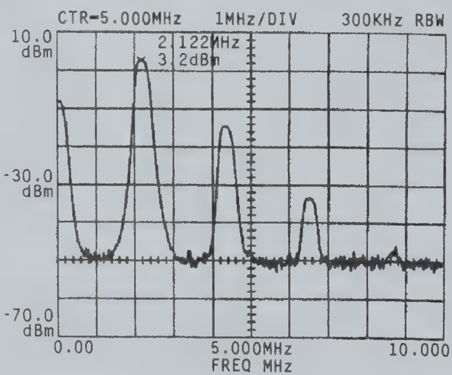
"VFO"
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N
SEC 2
SECTION
VARICAP TUNED VFO
Built by:
Date:
Chk'd
Final
DETAIL T6
FT37-61
16T PRI
8T SEC
DETAIL D7
CATHODE K
ANODE A
FOOTPRINT 1.5"H x 2.5"W
DETAIL L1
T50-7
44 Turns
TX VFO
RX VFO
"W13"
"W8"
"VCC4"
"VCC5"
"VCC7"
"W14"
Wire Link
Wiper
POT 2
TUNE
10-TURN POT -
Use 10-turn Counting Dial
SINGLE-TURN POT -
Use Multi-turn Vernier Dial

SEQ#2: VFO con't.
Varicap diode D7 looks like a TO-92 transistor, but with only 2 leads. Ensure it is installed properly. See the detail for identifying the anode and cathode on the SEQ#2 drawing.

Testing.
Once built, this section can be tested quite easily if you have a general coverage receiver. The VFO needs to tune nominally from **2.085 MHz to 2.185 MHz**. Attach a short length of wire to the pad marked "Rx VFO". Power it up by applying 12 to 13.8 vdc (use a fused supply) to all of the pads marked Vcc, and tune your receiver until you hear the VFO. It should be quite strong. If you have a counter or oscilloscope, they can also be connected to the same output pad for measurement and signal observation. The unloaded output from the secondary of T6 should be around 3 volts peak to peak.

2N2/40 on the Test Bench

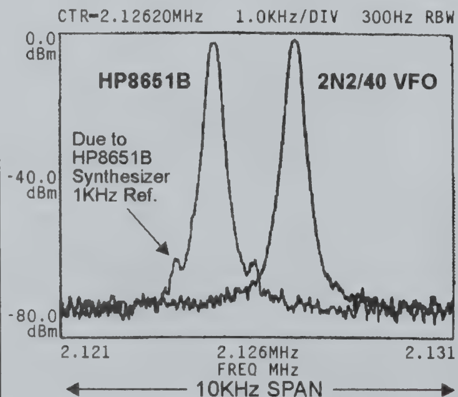
VFO Power & Spectral Output



As Jim discussed in his article, harmonic power from the VFO is reduced by the inductance of T6-primary and C15. Without C15, the 2nd harmonic (4.2MHz) is only down about 6dB. With C15, as shown here, the 2nd harmonic is down 18dB (-18dBc) and the 6.3MHz 3rd Harmonic is -37dBc. The lower the harmonic content of the VFO (LO), the less image power out of the mixer. The spectrum here was measured at the center-tap of T5 (RX LO power).

VFO close-in Purity (Phase Noise)

Oscillator Close-in Sideband Power
2N2/40 VFO vs. HP8651B Sig. Gen.



Oscillator phase noise is the very small "wiggling" of the oscillator that causes power to appear in the very close-in (<20KHz) sidebands. Of interest to QRP rigs is <2KHz, as this will cause noise power in the detected CW audio and other problems. It is also a measure of oscillator quality and stability. The VFO in the 2N2/40 has very low noise power, being -65dBc at 750Hz and -68dBc at 2KHz for a phase noise of slightly less than 2°. The 2N2/40 VFO close-in spectrum is shown here compared to an HP 8651B signal generator.

❸ Receiver "Front End"

Schematic	Assembly Dwg.
Sht. 1	SEQ. #3

- RX T/R Switch
- Input Filter
- Switchable RF Amplifier
- Diode Double Balanced Mixer

Circuit Description.
The RX T/R switch configuration used in the 2N2/40 is not the first design that I actually built. My first design was more robust, but required too many transistors to generate the drive signals, and in the end, had to be scrapped. This design, I believe, comes from Roy Lewellan, W7EL and has been used by many others. While it works very well for such a simple design, it does have some limitations. Its main fault is that it doesn't handle strong signals well, which could lead to third order intercept problems. However, if your 2N2/40 isn't used at field day or in similar situations, where really strong signals are present, it does just fine.

As originally implemented, the circuit used a trimmer at TC9, a 12uH inductor at L8, and the series resonance of this pair could be tuned. However, the loaded Q of the circuit is quite low, about 4, which makes the tuning so broad that this capability is wasted. I'd recommend building this circuit with TC9 being a fixed 47pF capacitor, and L8 being a 10uH molded inductor. That saves a trimmer, and the performance is virtually unchanged.

The input filter receives the signal from the T/R switch. This filter is a classic double tuned band pass filter, using light coupling between the two resonators. Its half power bandwidth is about 150 KHz with the component values used. The secondary of input transformer T1 has an inductance of 3.6uH, and is resonated at 7.05 MHz with capacitor C1 and trimmer TC1. The three-turn primary provides a 50 ohm match to the antenna.

Output transformer T2 uses a 7-turn link, to match the 350 ohm input impedance of the r.f. amplifier. T2 is tuned to resonance with capacitor C3 and trimmer TC2. The coupling between the two resonators is 3pF. In the prototype rig, this capacitor is 3.9pF, but additional circuit tests suggests a 3pF value provides flatter frequency response over the desired 7.0 to 7.1 MHz region, without appreciable change in overall 3dB bandwidth. It should also make input tuning a bit less critical.

The r.f. amplifier is based on a common emitter design. With the component values used, it has 10 dB of power gain. Computer modeling shows that it can handle an input signal in excess of +13 dBm without distortion or going into gain compression. Another 10 dB of gain can be accomplished by paralleling emitter resistor R4 (82 ohms) with a 12 ohm resistor (R65). My 2N2/40 has a front panel switch for doing this, although I don't use the 20 dB gain position very often. Running the higher gain also reduces the input impedance to about 100 ohms, causing a mismatch with the input filter. However, it does let you to hear really weak signals, under the right conditions. A 4:1 impedance ratio bifilar transformer, T3, is used to couple the output to the receiver's diode DBM.

The receiver diode double balanced mixer (DBM) in the prototype rig was constructed on a very small (1/2 inch X 3/4 inch) piece of single sided PC board material, instead of on the main substrate. The reason for doing this was so that it could be easily replaced (after Dayton, of course) with a commercial DBM if my

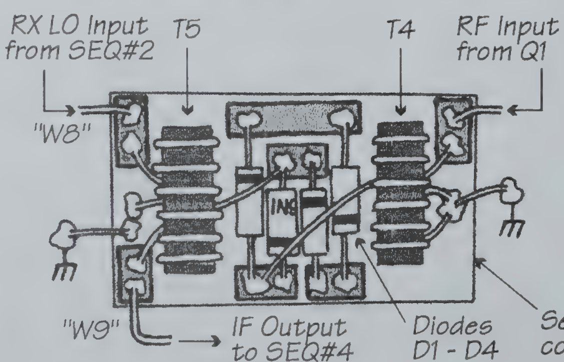
home-brew unit didn't work well. That DBM implementation was detailed in Paul Harden, NA5N's "QRP Hints and Kinks" section of the Summer 1998 issue of QRPp. (see below). I'm not sure that I would recommend building yours quite that small, unless you have lots of patience! The provided layout essentially uses the same geometry, but with more room between the various components. However, keeping the all the leads as short as possible helps maintain the balance necessary for the DBM to work well. Also, the 1N4148 diodes should be matched for forward resistance. Just measure a bunch, and pick 4 that are within a 1 ohm of each other. Since the diode leads are cut short, don't keep the soldering iron on these connections very long, or you will overheat the diode and change it's forward resistance characteristics.

Assembly.
This section should be built from the (rear panel end) to the bottom (towards front panel edge), and from right to left. Start with the input pad for the T/R switch (Port A on the schematic, or wire "W7" on the assembly drawing) and end with the DBM on the bottom left. Once this portion is built, it too can be tested, using a general coverage receiver. I'm assuming that you have the VFO built and working correctly and its output is routed to the pad labeled VFO (Term RX VFO, wire "W8" from dwg. SEQ#2). Solder a temporary jumper across the two pads labeled Pot 5 Wiper and Pot 5 High (RF Gain control).

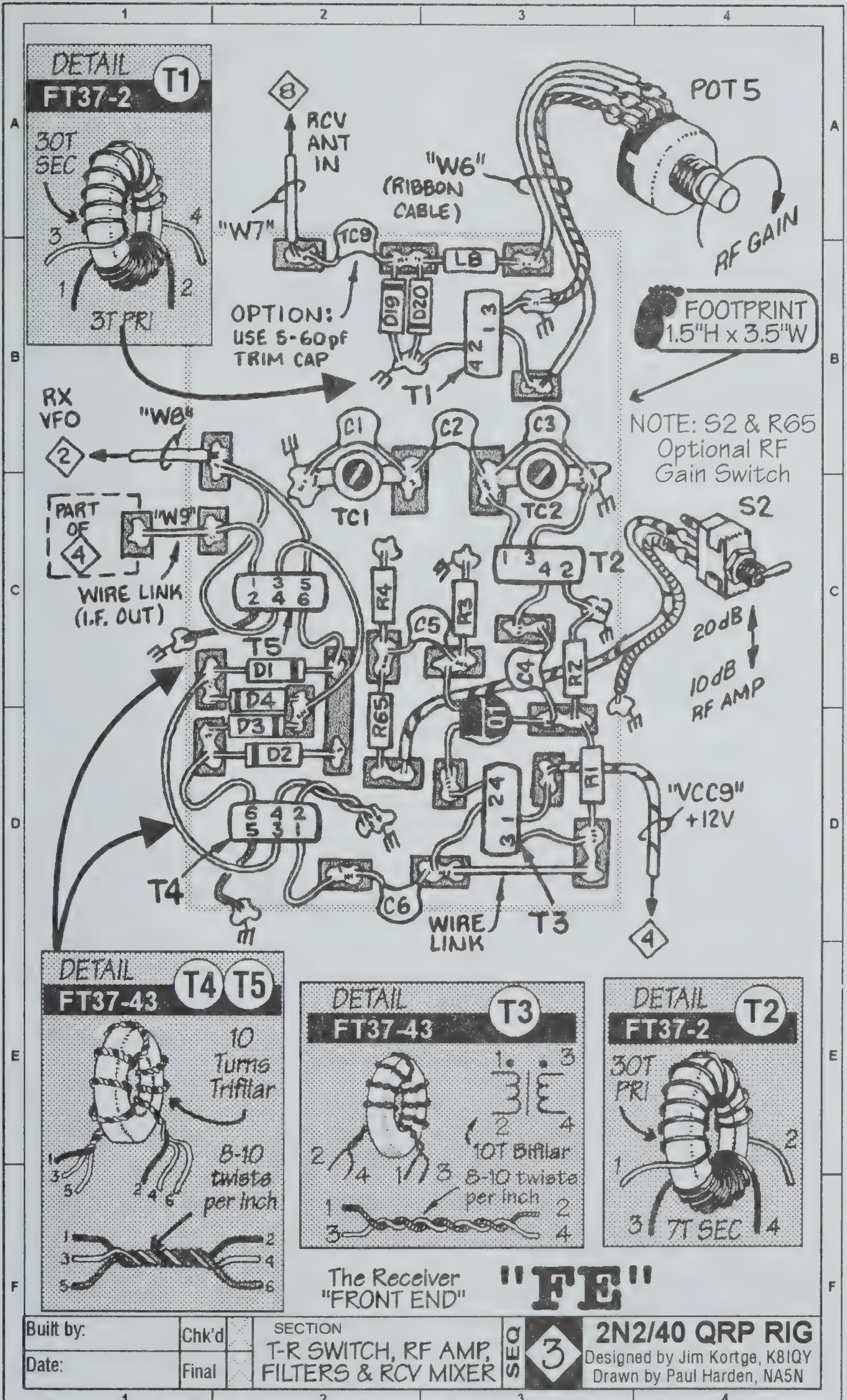
Testing.
Set the VFO to its mid-frequency, 2.135 MHz. Attach an antenna or 4-5 foot piece of wire to the pad labeled A. (Wire "W7"input). Connect the output pad labeled "C" (Wire link "W9") to the antenna input on your receiver with a piece of coax cable. Tune the receiver to 4.915 MHz. Using a signal generator, or a QRP rig fed into a dummy load, generate a signal on 7.050 MHz. You should find a signal very near 4.915 MHz, the 2N2/40 i.f. frequency.

Once you find the signal, peak the input trimmers TC1 and TC3. Go back and forth between these two a couple of times until it is as strong as you can get it. If you built this section using a trimmer for TC9, peak that trimmer also. At this point, you should be able to leave the receiver tuned to 4.915 MHz, and tune the 40 meter CW band using the VFO. The general coverage receiver is acting as our crystal filter, i.f. amplifier, and detector. We'll build those next.

Double Balanced Mixer (DBM) -- Alternative Layout



This alternative approach builds the DBM on a separate piece of copper clad. It would be useful for builders wanting to experiment with different diodes for the mixer, or to remove later to install an SBL-1, etc.


DETAIL
FT37-2
T1
30T SEC
3T PRI
RCV ANT IN
"W7"
"W6" (RIBBON CABLE)
POT 5
RF GAIN
TC9
LB
D19
D20
OPTION: USE 5-60pf TRIM CAP
T1
FOOTPRINT 1.5"H x 3.5"W
RX VFO
"W8"
C1
C2
C3
TC1
TC2
NOTE: S2 & R65 Optional RF Gain Switch
S2
PART OF
"W9"
WIRE LINK (I.F. OUT)
T5
R4
R3
C5
T2
20dB
10dB RF AMP
D1
D4
D3
D2
R65
C4
R2
Q1
R1
"VCC9" +12V
T4
C6
WIRE LINK
T3
DETAIL
FT37-43
T4
T5
10 Turns Trifilar
8-10 twists per inch
DETAIL
FT37-43
T3
10T Bifilar
8-10 twists per inch
DETAIL
FT37-2
T2
30T PRI
7T SEC
The Receiver "FRONT END"
"FE"
Built by:
Date:
Chk'd
Final
SECTION
T-R SWITCH, RF AMP, FILTERS & RCV MIXER
SEQ
3
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

4 Crystal Filter/IF Amp

Schematic	Assembly Dwg.
Sht. 2	SEQ. #4

- Mixer Amplifier
- Variable Crystal Filter
- I.F. Amplifier

Circuit Description.
These elements make up the next major section of the receiver. With the addition of the Local Oscillator (RX LO) and the Product Detector in the section SEQ#5, we have essentially a complete receiver, down to detected audio. We'll get to that point shortly.

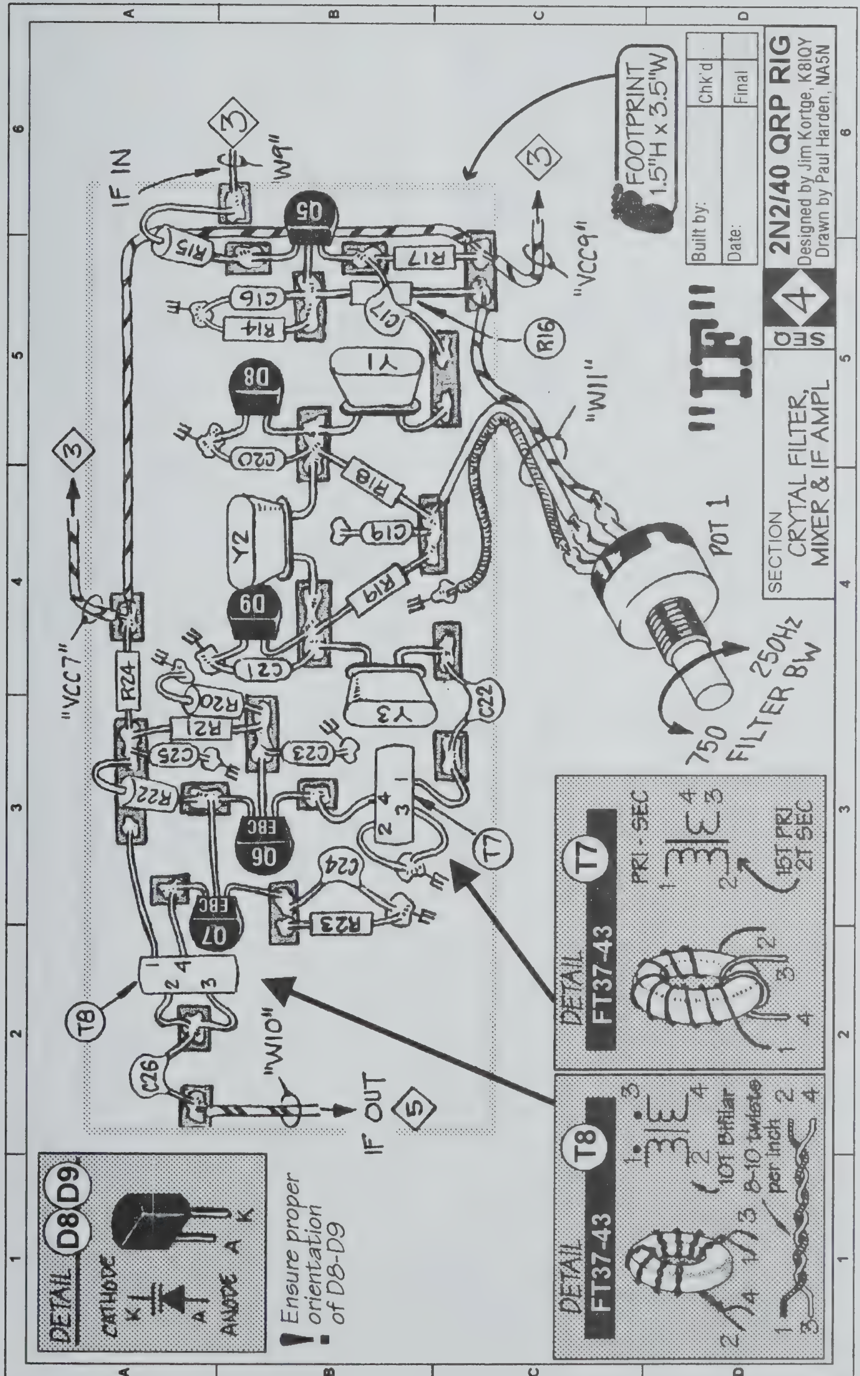
Mixer Amplifier. The diode DBM IF output signal (from SEQ#3) is fed to common base amplifier Q5. I've not seen this done before, and am not sure why. Since one of the goals in terminating a DBM is to have it working into a constant impedance load, this amplifier fits the bill nicely.

As configured, the input impedance is constant at 50 ohms resistive, from DC to beyond 30 MHz. Using this circuit, we don't need a diplexer, nor do we need an attenuator, to keep the load on the mixer i.f. port constant. In addition, with the 270 ohm collector resistor, this amplifier produces about 6 dB of power gain. It also has reasonable output to input isolation, so that impedance changes from the downstream crystal filter don't reflect back to the mixer.

Variable IF Crystal Filter. Following the mixer amplifier is a 3 pole, variable bandwidth (VBW), Cohn style crystal filter, consisting of Y1 to Y3. It uses matched 4.915 MHz series mode crystals. The bandwidth can be changed from about 700 Hz, down to 300 Hz. (See the NA5N measurements on page 26). Bandwidth control is accomplished using a pair of MV2115, voltage variable capacitance diodes. These diodes provide a capacitance change of about 100pF, as the voltage on them is varied from 0 to 13.8 vdc. Bandwidth control voltage is provided by a variable potentiometer, POT1. The 270 ohm source and terminating impedances for the filter are provided by collector resistor R17, on the input side, and the transformed input impedance of Q6, the first i.f. amplifier transistor, on the output side. The output impedance transformation is done with transformer T7, which has a 15-turn to 2-turn turns ratio, and approximately 56 to 1 impedance ratio. The 2-turn secondary should be wound on the "cold" (grounded) end of the primary.

The IF Amplifier. Following the VBW crystal filter is the intermediate frequency amplifier, Q6 and Q7, using another somewhat unconventional design. My first thought for the i.f. amplifier was to use a common cascode arrangement, i.e. a common emitter amplifier driving a common base amplifier. That configuration was modeled, and although it provided plenty of gain, it showed a wide variance in the input impedance with frequency. I felt the crystal filter ought to be working also into a constant load, just like the receiver DBM, for optimum performance. This led to building a new computer model which had the common base amplifier first (Q6), driving a common emitter amplifier (Q7).

As with the common cascode configuration, the two transistors, Q6 and Q7, are direct coupled. Modeling once again showed this configuration could supply more than enough gain, but more importantly to me, the input impedance was constant over a very wide frequency range. However, the input impedance is only a few ohms, which resulted in the wide turns ratio transformer, T7, being required to couple the


2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N
Built by:
Date:
Chk'd
Final
SECTION
CRYTAL FILTER,
MIXER & IF AMPL
"IF"
FOOTPRINT
1.5"H x 3.5"W
IF IN
"W9"
"VCC9"
"VCC7"
"W11"
"W10"
IF OUT
POT 1
750
250Hz
FILTER BW
DETAIL
CATHODE
ANODE
Ensure proper orientation of D8-D9
DETAIL
FT37-43
10T Bifilar
8-10 twists per inch
DETAIL
FT37-43
PRI - SEC
15T PRI
2T SEC

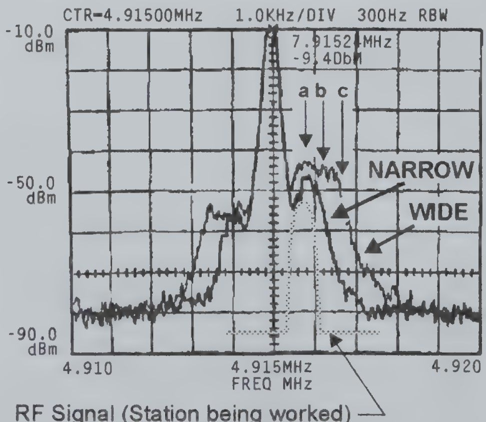
crystal filter into the amplifier. With the component values shown, the power gain of this stage is nearly 50dB, with a response peak at 4.9 MHz. Output is taken from a bifilar wound, 4:1 impedance ratio transformer, T8. The output impedance from this stage is 50 ohms, suitable for driving the product detector. This amplifier also shows no stability problems when properly terminated.

Assembly.
I'd recommend building this portion of the rig by starting at the right, near the DBM output in SEQ#3, and building toward the left until you're done with the i.f. amplifier. Probably the only critical thing here is keeping as much room between the i.f. input and output transformers, T7 and T8, as you can. This will help to insure stability. Placing the transformers at right angles to each other also minimizes coupling, but is not required.

Testing.
If you would like to test the rig at this point, connect the output of the i.f. (port pad marked "IF Out," or wire "W10") to the antenna input of your general coverage receiver, again using coax or a shielded scope probe. Tune the general coverage receiver to 4.915 MHz and power up the 2N2. This time, signals should be very strong, since we now have another 50 dB of gain from the i.f. amplifier. In fact, on very strong signals, you may have to reduce the r.f. gain of the communications receiver to keep from overloading it. You can also play around with the VBW crystal filter by grounding the pad marked "Pot 1 Wiper" or by taking this point to the Vcc supply. When this pad is grounded, the filter will be in its most "narrow" position, and when at Vcc, the filter will be running in its "wide" position. Of course, if you hook up POT1, you can set the filter to any passband width within its capability.

2N2/40 on the Test Bench

The Variable Bandwidth IF Crystal Filter



This spectrum analyzer display was made by injecting a -70dBm wideband noise source into the antenna (an S3-S4 signal) to "paint" the overall shape of the IF response.

This spectrum analyzer display shows the IF bandwidth at the crystal filter output for both the ***wide*** and ***narrow*** settings on the VBW control (POT1). Point "a" is the IF peak. The -3dB points are shown at "b" (narrow) and "c" (wide). This shows a bandwidth of 800Hz in the wide setting, and 300Hz at narrow, for a very nice variable IF filter for CW reception. If there was a signal 1KHz higher, note it would be attenuated by 6dB in *wide*, and in *narrow* by 28db! This gives the 2N2/40 good selectivity and rejection of nearby interfering signals.

–NA5N

5 RX LO Oscillator and Product Detector

Schematic	Assembly Dwg.
Sht. 2	SEQ. #5

Circuit Description.
The receiver local oscillator is a Colpitts configuration, just like the VFO. Perhaps the only unique feature of the circuit is tapping the output off the split emitter resistor pair, R29 and R28 and using a parallel tuned circuit to shape the waveform and reduce harmonics. I'm not sure going these extra steps has any payoff, but the output waveform is a clean sinewave. Something that may not be obvious about this oscillator setup is that its frequency is below the i.f. passband because this rig uses the Cohn filter as an upper sideband filter, instead of the more traditional, lower sideband arrangement. Lowering the crystal frequency is accomplished by adding inductive reactance from L2, in series with the crystal. Trimmer TC5 lets us adjust the amount of inductive reactance. For proper receiving, the frequency of this local oscillator is adjusted to be 750 Hz *below* the 4.915 MHz passband. When this signal is mixed with the i.f. signal in the product detector, our desired 750 Hz CW note is recovered.

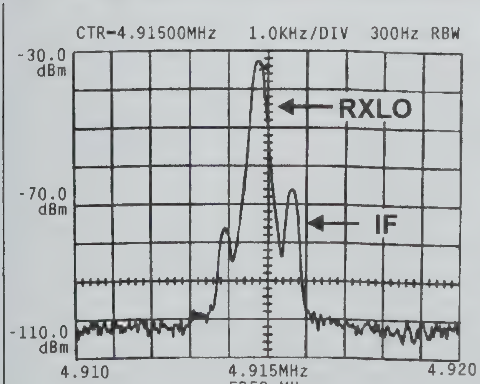
The product detector is simply a two-diode, single balanced mixer. The i.f. signal is mixed with the receiver local oscillator producing principally two frequencies. The sum frequency is at 9.83 MHz and is shunted to ground by the reactances of C27 and C28. The difference frequency is 750 Hz, and adjustable by changing the frequency of the receiver local oscillator (also called the BFO -- the Beat Frequency Oscillator) via trimmer TC5. This is the recovered audio that will drive the speaker after it is amplified.

Assembly.
The RX LO oscillator and the Product detector are built to the left of the IF/crystal filter section to the left edge of the board. Layout is not tight, but plan things out to ensure you're not running out of "board" space.

Note T8, the trifilar wound transformer. Details for winding T8 are on the assembly drawing.

Testing.
There's not much to test at this point. Let's build the next section, the audio amplifier, and then we'll have a complete receiver to test and align.

2N2/40 on the Test Bench

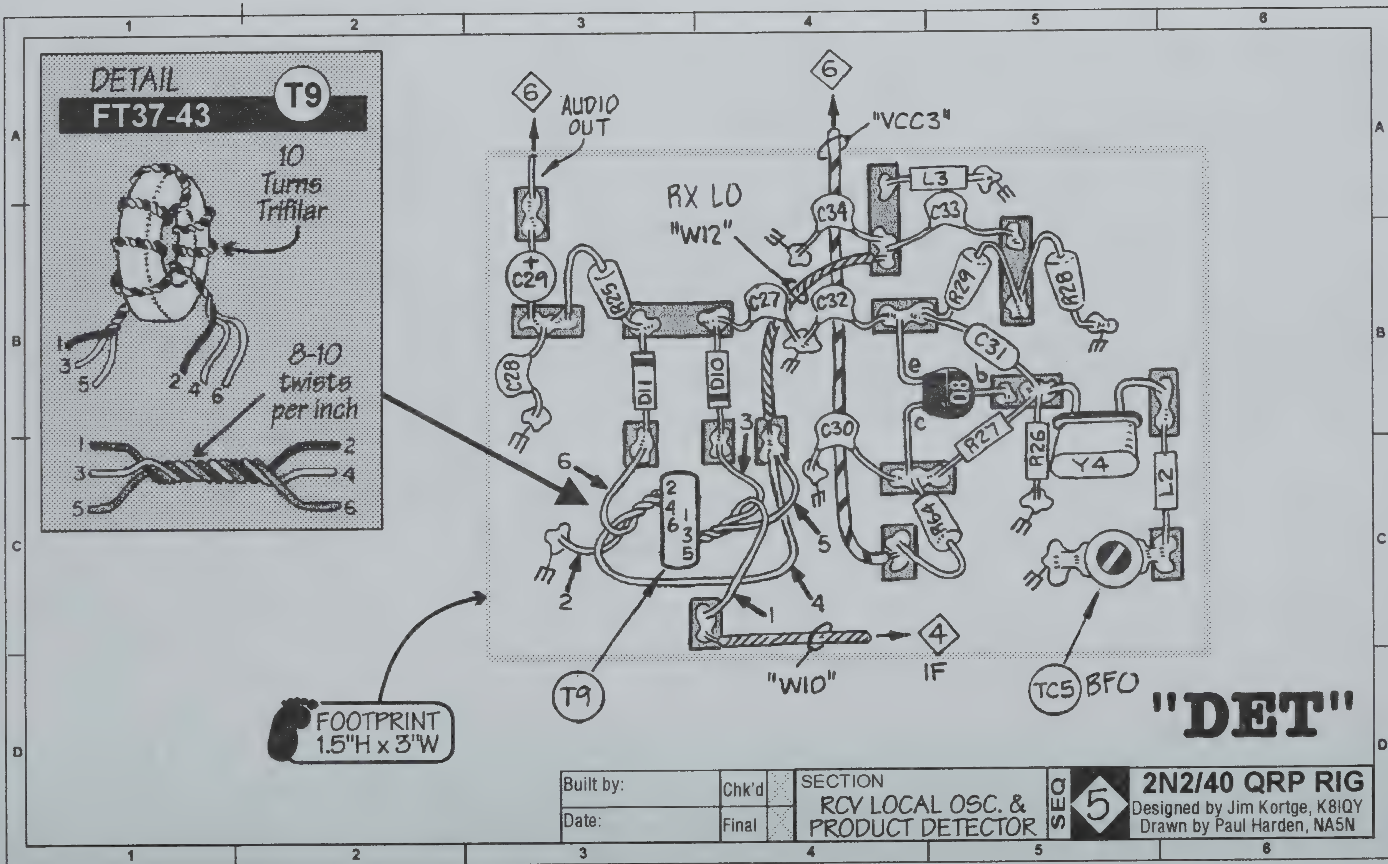


Input spectrum of the Product Detector

This shows how the product detector works to generate the desired "CW tone." The two input signals are:
4.915600 MHz - IF
4.914800 MHz - RXLO

The difference frequency is 800Hz ... the CW *audio* tone that will be present at the Product Detector output. The actual tone is set by TC5 - the BFO, which varies the RXLO frequency.

-NA5N


DETAIL
FT37-43
T9
10 Turns Trifilar
8-10 twists per inch
AUDIO OUT
RX LO
"W12"
"VCC3"
"W10"
IF
TC5 BFO
T9
FOOTPRINT 1.5"H x 3"W
C28
C29
R25
D11
D10
C27
C32
C34
C33
L3
R29
R28
C31
C30
08
e
b
c
R27
R26
R64
Y4
L2
"DET"
Built by:
Date:
Chk'd
Final
SECTION
RCV LOCAL OSC. & PRODUCT DETECTOR
SEQ
5
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

6 Receiver Mute and Audio Amplifier

Schematic	Assembly Dwg.
Sht. 2	SEQ. #6

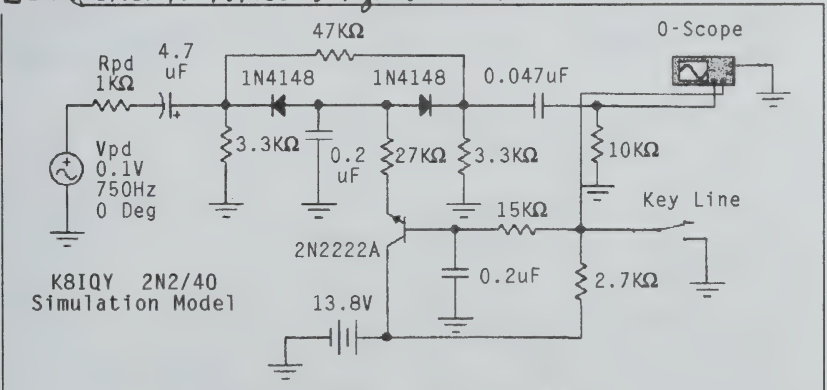
Circuit Description.
The receiver mute circuit passes recovered audio to the audio amplifier when the rig is in receive mode. In this condition, diodes D12 and D14 are forward biased, and have very low forward resistance. The bias is provided by transistor Q9, which is turned "on" by the "Rx" signal applied to the base. When the rig transmits, drive is removed from Q9, causing the bias on D12 and D13 to be removed. These diodes now appear as open circuits, and audio is blocked. A small amount of side-tone audio is passed on to the audio amplifier during transmit by resistor R31. Sidetone audio is provided by having the receiver listen to the transmitter. Caps C35 and C36 provide delays to keep audio "thump" to a minimum during receive-to- transmit and transmit-to-receive transitions.

PSPICE Analysis.
Before leaving this section, it seems appropriate to show an example of the analysis that can be done with today's computer modeling tools. In this case, the software product is the Personal Edition of Electronic Workbench. The company that produces this system offered it at reduced pricing this summer, so EWB was purchased. It works much like the MicroSim DesignLab (PSPICE) demo that I had been using, but is even more full-featured. When the educational Manhattan/Elmer 300 Project is done this winter over the internet, many more of these analyses will be discussed and shown. This one is just to whet your appetite!

The computer model of the receiver mute circuit is shown below.

As you can see, this simulation circuit is a duplicate of the real thing shown in the 2N2/40 schematic. Product detector output, which is the signal source for this simulation, is the ac source labelled Vpd, set for 100 millivolts rms at 750 Hz. The product detector source impedance is the 1K resistor labelled Rpd. The small oscilloscope in the upper right hand of the model is a simulated scope within EWB, and can be expanded to show waveforms while the simulation is running. That will be shown next.

2N2/40 PSPICE Design Simulation

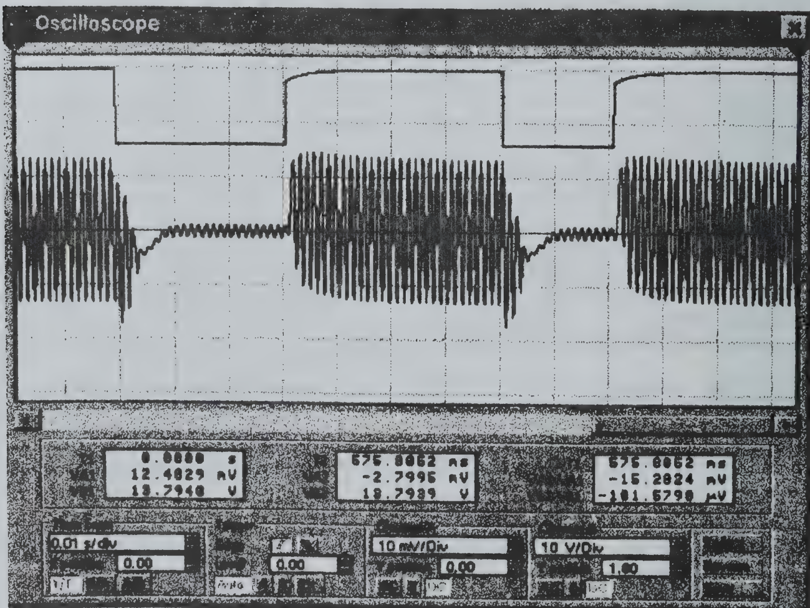


RX MUTE SIMULATION MODEL

The "key line" can be toggled while the simulation is running by tapping the space bar on the computer keyboard, so that the transitions from "receive mode" to "transmit mode" and back again can be studied. Actual CW could be simulated by hooking up the EWB digital word generator in place of the key line switch, but that's overkill for this simple circuit.

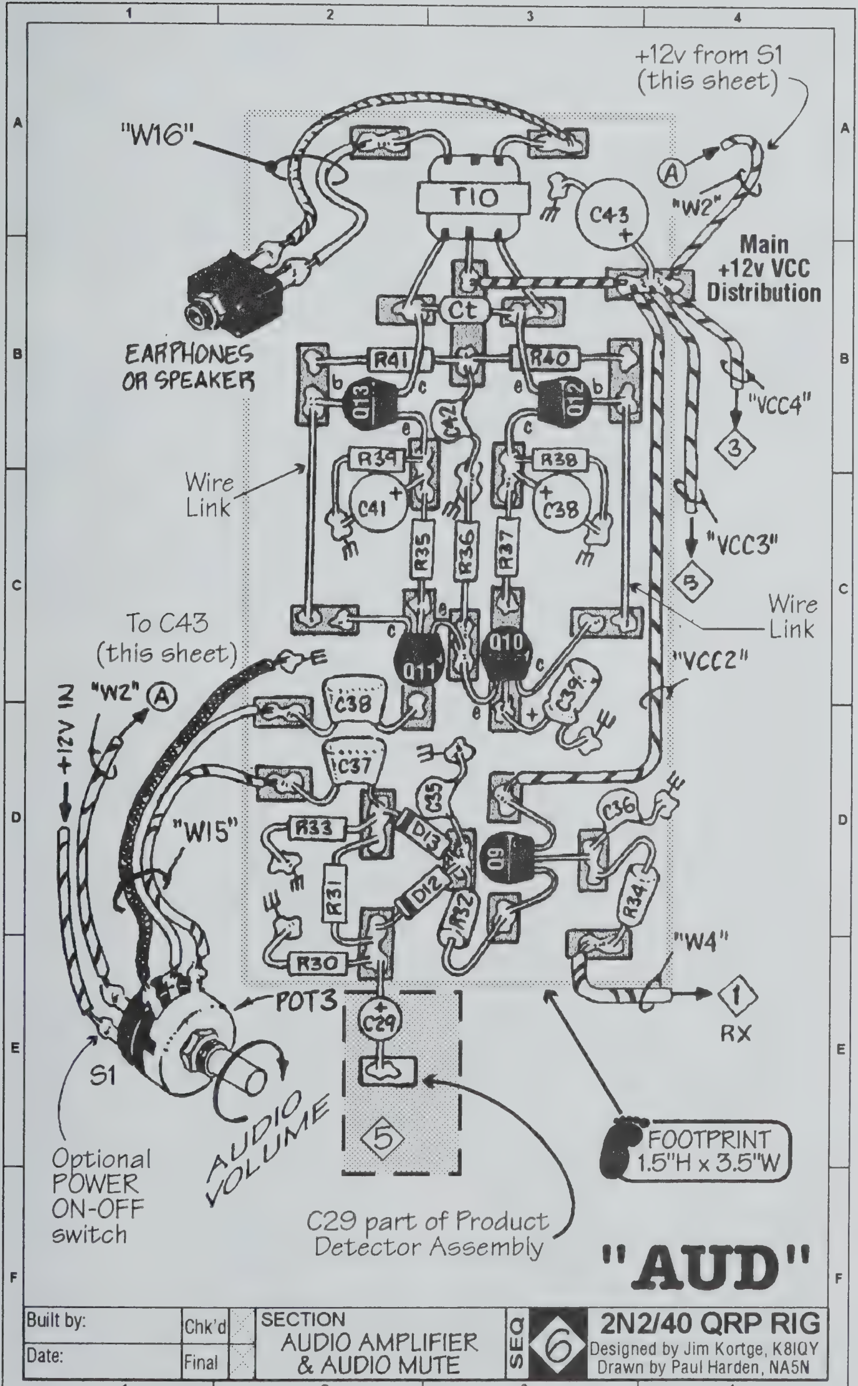
The resulting waveforms as the circuit is keyed is shown below.

The upper trace is the "key line" signal shown at 10 volts/division. The bottom trace is the output that is present on the wiper of the volume control potentiometer, POT3, at the full volume setting, shown at 10 millivolts/division. You can clearly see the effects of R31, the 47K resistor which "leaks" a bit of audio through during transmit so that we have keying sidetone. It should be apparent from this example what a marvelous tool modeling is, and the help it can be for checking out ideas, studying circuits, etc. without having to build anything physical.



Finally, getting back to the actual 2N2/40 ... the audio amplifier rounds out the receive chain.

The Push-Pull Audio Amplifier is another circuit of my design. Incoming audio is applied to the base of transistor Q11. As can be seen, Q11 shares a common emitter resistor, R36, with Q10. Q10's base is grounded for audio purposes, so it becomes yet another common base amplifier, being driven in its emitter from the signal provided by Q11. The collector signals on Q11 and Q10 are of equal amplitude and 180 degrees out of phase with each other. These signals are then directly coupled to the bases of Q13 and Q12, where they are further amplified. Transformer T10 couples the push-pull signals from the collectors to the speaker. Note that the biasing of the input pair of transistors is derived from the emitters of the output pair. The large capacitors on the output


+12v from S1
(this sheet)
"W16"
T10
C43
"W2"
A
Main
+12v VCC
Distribution
Ct
EARPHONES
OR SPEAKER
R41
R40
Q13
Q12
C42
"VCC4"
3
R39
R38
Wire
Link
C41
C38
R35
R36
R37
"VCC3"
5
Wire
Link
To C43
(this sheet)
Q11
Q10
"VCC2"
"W2"
A
+12V IN
C38
C39
C37
C35
C36
"W15"
R33
D13
Q9
R31
D12
R32
R34
"W4"
R30
POT3
C29
1
RX
S1
AUDIO
VOLUME
5
FOOTPRINT
1.5"H x 3.5"W
Optional
POWER
ON-OFF
switch
C29 part of Product
Detector Assembly
"AUD"
Built by:
Date:
Chk'd
Final
SECTION
AUDIO AMPLIFIER
& AUDIO MUTE
SEQ
6
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

The large capacitors on the output pair emitters bypass all audio. Capacitor Ct is chosen to resonate the primary inductance of T10 at 750 Hz, thereby providing additional CW signal selectivity. In the prototype rig, this capacitor is 0.082uF. While I haven't measured the power output of this amplifier, it is more than enough to drive a speaker to uncomfortable levels at full volume. It also has very low internal noise.

Assembly.
This layout is a bit more open than the others, since the size of T10 could vary depending on the part source. Circuitry should be built from T10 down. Nothing is very critical here, since we're now dealing with audio, and it's a bit easier to control. When you get to the audio amplifier, note that the leads of base bias resistors R35 and R37 need to pass under their respective transistor bodies, Q10 and Q11 (that is, Q10-Q11 sit on top of R35 and R37, or closer together than they appear on the SEQ#6 assembly dwg.) This is also true for resistors R40 and R41. I'd recommend that all of these resistors be soldered in first, before adding the other components. Before testing. you should wire in POT3, so you have a volume control. **At this point, you now have a complete receiver.**

Testing.
The only test to perform at this juncture is to see if it works in its entirety. Connect an antenna to the Port A pad, and a speaker on the T10 secondary pads, and apply fused power. If you've done the building correctly, and have passed the previous tests, you should have a 2N2/40 receiver that is working, maybe even hearing signals, but as yet, not aligned. Here is how to do the alignment.

2N2/40 on the Test Bench -- Receiver Alignment

Receiver Alignment -

✔ Set trimmer potentiometer TC5 to its maximum capacity position by either listening to the receiver local oscillator on another receiver tuned to approximately 4.914 MHz, or by measuring the output frequency of the local oscillator by attaching a probe to the ungrounded end of L3 and adjusting TC5 for the lowest frequency obtainable.

✔ Tune the receiver to a signal, or if possible, generate a signal about mid-band, around 7.050 MHz. Tune across this signal by rotating tuning potentiometer POT2. Notice that as the tuning potentiometer is rotated clockwise, the audio pitch of the signal goes lower.

✔ Listen for a peak in audio response as the signal is tuned. We want this peak to occur at about 750 Hz. With TC5 set for maximum capacity, the peak is probably upwards of 1500 Hz. Slowly rotate TC5 to a lower capacity setting. Go a little at a time, and retune the receiver, listening for the audio peak. You will hear it progressively moving to a lower pitch.

✔ Repeat the adjustment of TC5 and retuning the receiver until the pitch is where you like to listen to CW, and is the loudest you can make it. That's it.....the receiver is aligned.

What this does is place the receiver local oscillator frequency about 750 Hz below the center of the crystal filter passband. Remember, the crystal filter is being used as an upper sideband filter. To confirm that everything is working as it should, find a SSB station and see if you can tune in the audio so that it is intelligible. If you've done the alignment correctly, you should not be able to properly tune in the signal, since the station is operating on lower sideband, and the receiver is listening to the upper sideband.

– K8IQY

You're now completed with the 2N2/40 receiver portion. Next, we'll build the transmitter stages. Your receiver should look something like this. This is a photo of the the RXLO, Product Detector and Audio stages of Jim's first 2N2/40 rig, which differs only slightly from his 2nd version that this construction article is based.

7 TX Local Oscillator, Mixer & Amplifier

Schematic	Assembly Dwg.
Sht. 3	SEQ. #7

Circuit Description.
The Tx Local Oscillator, Single Balanced Mixer, and Cascode RF Amplifier - These elements make up the first section of the transmit strip.

TX Local Oscillator. The transmitter begins with another crystal oscillator, Q14 and associated circuitry, used to generate a CW signal at 4.915 MHz. This circuit is virtually a duplicate of the receiver local oscillator. Output signal is taken from the emitter through a 47pF capacitor, C46.

TX Mixer. The TX LO signal is fed to a diode, single balanced mixer (SBM) along with a signal from the VFO, which is applied to the SBM through capacitor C48. The SBM consists of a trifilar wound transformer T11, along with four 1N4148 diodes, D14 through D17. Details for winding the trifilar transformer, T11, is shown on the SEQ#7 assembly drawing. As with the receiver DBM, the diodes should be matched for forward resistance. The sum of the Tx LO signal and VFO signal produce an output at 7 MHz that is used in the transmit strip. The difference frequency, along with the original mixer signals and higher order mixer products, are filtered out by the tuned input and output circuits of the next stage, a cascode RF amplifier.

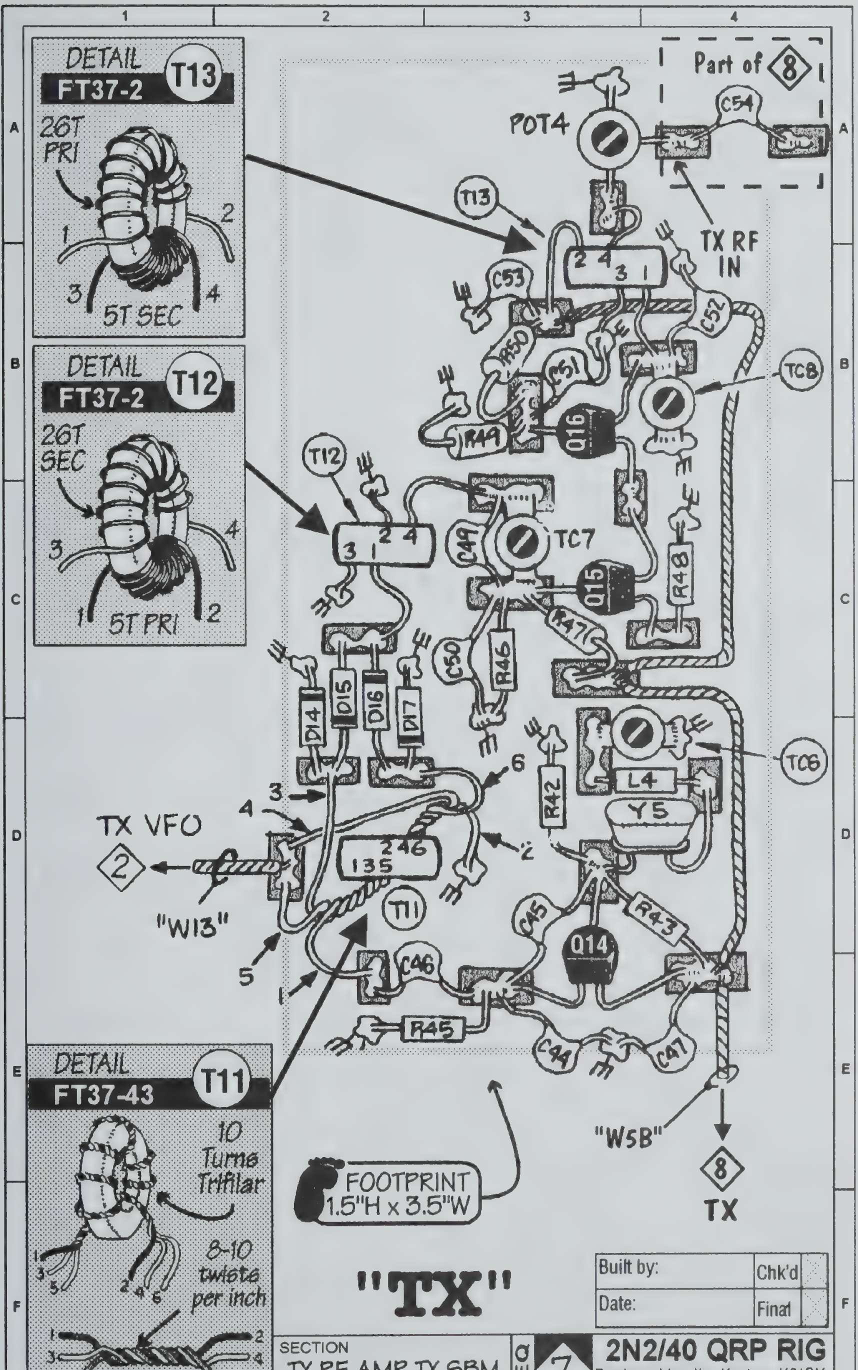
The TX Cascode RF Amplifier uses a conventional grounded emitter stage, Q15, direct coupled to a grounded base stage, Q16. Total power gain for this transistor pair is on the order of 40 dB. The input is a link-coupled, tuned circuit comprised of T12 and capacitors C49, C50, and trimmer TC7. A tuned output is employed using another link-coupled transformer, T13 and capacitor C52 and trimmer TC8. Output from this stage is taken from the 5-turn secondary link, and feeds the power control potentiometer, POT4. As a point of reference, the 26-turn windings on T12 and T13 should measure at 3.0uH. Maximum power output from this stage is about 10 milliwatts, or 0 dBm. However, with the 2N2/40 running at 1.5 watts output, this stage only needs to feed the driver with 0.2 milliwatts, or -6 dBm.

Assembly.
I'd recommend starting with the single balanced mixer and then follow that with the local oscillator. These two sections could almost be done together, since they are adjacent to each other, and tightly integrated.

When the local oscillator and single balanced mixer have been completed, build the cascode RF amplifier. Items that are critical here are the placement of the input and output transformers. They should be as far apart as you can get them, and ideally, at right angles to each other. They're not show in that orientation on the layout for clarity, and will also work fine as shown.

Testing.
Once all of the elements are completed, they can be tested following this procedure.

The Tx local oscillator can be tested by itself by applying power to the Tx lead, and listening for a signal at 4.915 MHz on a general coverage communications receiver. You can also attach a frequency counter probe to the mixer side of


DETAIL
FT37-2
T13
26T PRI
5T SEC
DETAIL
FT37-2
T12
26T SEC
5T PRI
DETAIL
FT37-43
T11
10 Turns Trifilar
8-10 twists per inch
Part of 8
C54
POT4
TX RF IN
C53
C52
R50
C51
TC8
Q16
R49
T12
TC7
C49
Q15
R48
R47
C50
R46
D14
D15
D16
D17
TC6
L4
Y5
R42
TX VFO
2
"W13"
T11
C45
Q14
R43
C46
R45
C44
C47
"W5B"
8
TX
FOOTPRINT 1.5"H x 3.5"W
"TX"
Built by:
Chk'd
Date:
Final
SECTION
TX RF AMP, TX SBM MIXER & TX LO
SEQ
7
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

capacitor C46 to verify that the circuit is oscillating at the correct frequency.

Once all of the elements are complete, they can be tested following this procedure. Connect a short test lead or your counter probe to the wiper pad of POT4 and adjust POT4 to maximum by turning the screwdriver adjustment to the full CW position. Apply power to the receiver in the normal manner. Apply power to the pads labeled Tx through a 1N4004 or equivalent diode, to simulate the approximate voltage level that will be present when the Rx/Tx switch is active. Listen for a signal at 7 MHz on a receiver. Verify that the signal changes frequency when the VFO is tuned. With the VFO set to a frequency of 2.135 MHz, its mid-frequency, adjust trimmers TC7 and TC8 for maximum signal. Go back and forth between these two a few times as there is some interaction. When you are done with this test, we are ready to build the other half of the transmit strip.

---

8 Transmit RF Driver, Power Amplifier & Output Filter

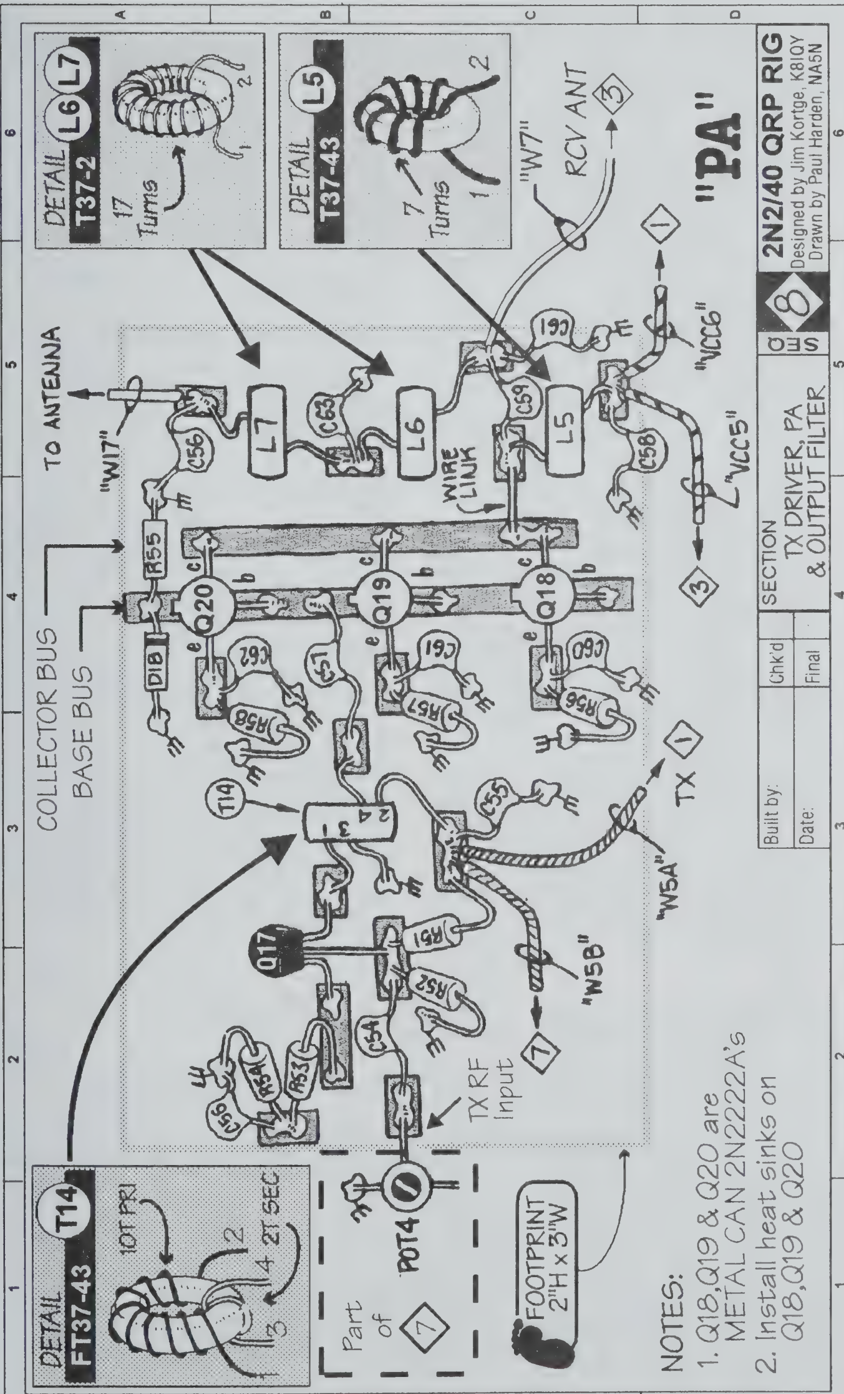
Schematic	Assembly Dwg.
Sht. 3	SEQ. #8

Circuit Description.
The Tx RF driver consists of Q17 and associated circuitry. Q17 is the first of the 2N2222A metal transistors used in the rig. A heat sink can be used on this transistor to manage the power being dissipated, but is not necessary. This stage is an untuned, class A amplifier, which produces the drive necessary for the final. Its output is via a 2-turn link on transformer T14. This transformer translates the higher collector load impedance down to the lower input impedance of the three parallel 2N2222A metal output transistors. Power output from this stage is about 10 milliwatts, or +10 dBm, with -6 dBm of drive from the previous stage.

The Power Amplifier (PA). The output from the TX driver is fed through capacitor C57 and on to the input circuitry of the final. This circuitry is a 1N4148 diode, D18, in parallel with R55, a 100 ohm resistor. Capacitor C57 charges minus to plus on the negative excursion of the drive signal. On positive going excursions, the voltage on C57 is added to the positive signal, thereby doubling the effective positive level, and providing more drive to the final transistors. This circuit is often referred to as a "dc restorer".

The final transistors, Q18, Q19, and Q20, are also **2N2222A metal case** types and *should be run with heat sinks*. This amplifier stage runs in class C, and measured efficiency is around 70 percent. Each transistor uses a bypassed 2.2 ohm resistor in its emitter to help keep the collector currents balanced, without having to gain match the 3 devices. Three transistors were used in the final because that's how many were left after building all of the rest of the rig (in keeping with the original rules of 22 maximum transistors).

I had expected to get about 1 watt output from the three 2N2222A's, and was pleasantly surprised to find that one can easily get 2 to 2.5 watts of output without excessive heating. I originally ran about 1.5 watts of output power without the heat sinks, but added them later, just to be on the safe side. The output impedance is about 50 ohms if the calculations are done with a Vcc of 12.5 volts and a power output of 1.5 watts, i.e. Vcc^2/2*Po.


DETAIL
FT37-43
T14
10T PRI
2T SEC
DETAIL
T37-2
L6
L7
17 Turns
DETAIL
T37-43
L5
7 Turns
"W7"
RCV ANT
TO ANTENNA
"W17"
COLLECTOR BUS
BASE BUS
WIRE LINK
"VCC6"
"VCC5"
"W5A"
"W5B"
TX
TX RF Input
Part of
POT4
FOOTPRINT 2"H x 3"W
"PA"
NOTES:
1. Q18,Q19 & Q20 are METAL CAN 2N2222A's
2. Install heat sinks on Q18,Q19 & Q20
Built by:
Date:
Chk'd
Final
SECTION
TX DRIVER, PA & OUTPUT FILTER
2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

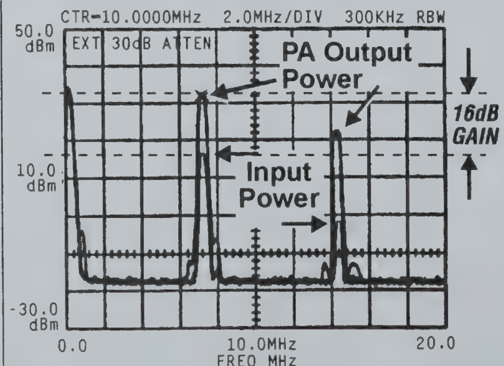
The Output Filter. The output power from the PA leads us to the output filter. This is a very standard, 5 pole, Chebyshev low pass filter taken out of table 11, page 2-44, of the 1988 ARRL handbook. It is filter number 86, using standard E24 capacitor values. The capacitors for this filter should be C61 and C65 at 430pF and C63 at 820pF. However, capacitor C61 is reduced to 360pF to compensate for the output capacitance of the 2N2222 finals, and the Rx T/R switch capacitance, that of TC9 (located on SEQ#1). These two sources add a total capacitance of 70pF in parallel with C61. All output capacitors should be silver mica units. Inductors, L6 and L7, should measure 1.6uH. Mine have fewer turns than the formula predicts, but measure at that value, using an AADE L/C Meter IIB. By the way, if you don't have one of these meters, get one! It is one of the best investments you will ever make in an inexpensive, very accurate, component test instrument.

Assembly.
The TX driver, PA and output filter is built on the last section remaining on the substrate board, as shown on assembly drawing SEQ#8. Note that the collectors and bases of PA transistors Q18, Q19 and Q20, are connected together in parallel by making two strips of copper clad to make two long pads. If you have difficulty making these long strips, an alternative would be to solder a buss wire (#20 solid or so) between two pads, ensuring they do not make contact with the ground board. Also ensure you allow sufficient clearance around the PA metal 2N2222A's for the heatsinks to be added.

Your 2N2/40 rig is now virtually complete. Ensure all wiring interconnecting the sections, such as the RX and TX terms, and all Vcc wiring is installed.

Testing.
You should add all external components (if you haven't already) with leads long enough for mounting in an enclosure. You can run it on the bench "as is." I did this with mine and had a blast making contacts with it sitting "nude" on the benchtop. To me, there is a certain fascination and beauty with having an operating rig on the bench, uncased, so that you can see all of the components, while watching the output power meter swing up as you key it in QSO. One can almost imagine all of the electrons moving here and there, doing their part to allow reception, or generating RF to be radiated.

2N2/40 on the Test Bench



Power Amplifier (PA) Power Levels

The 7MHz fundamental and 2nd Harmonic powers are shown at the input and output of the PA amplifier, *before the output filters.*

Input power at Q18-base is +16dBm (40mW) and the output is +32dBm (1.6W), showing Q18-Q20 provides 16dB of power gain.

-NA5N

Transmitter Alignment.
Before aligning the transmitter, be sure the rig is connected to a dummy load, since we will be keying it and generating r.f.

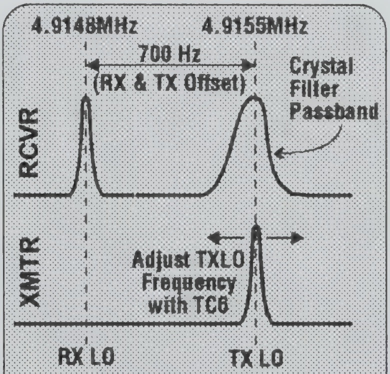
✔ Setting the transmitter local oscillator trimmer, TC6, to the minimum capacity position. Use the same method we used with the receiver to determine where this is. With TC6 at minimum capacity, the transmitted signal will be far above the center of the crystal filter. Our goal is to slowly move the transmit frequency down until it is in the center of the receive passband. When that happens, we will hear it at the same pitch as we hear a properly tuned CW station.

! *Do not keep the transmitter on the air continuously for longer than 20 seconds while making these adjustments. If you have a keyer, let it send a series of dits.*

✔ With the transmitter keyed, slowly turn trimmer TC6. As you do, you will eventually hear the transmit signal at a very high pitch as it enters the crystal filter passband from the higher frequency end. Keep turning until the pitch of the note heard is the same as a properly tuned CW station. When they are nominally the same, stop adjusting TC6.

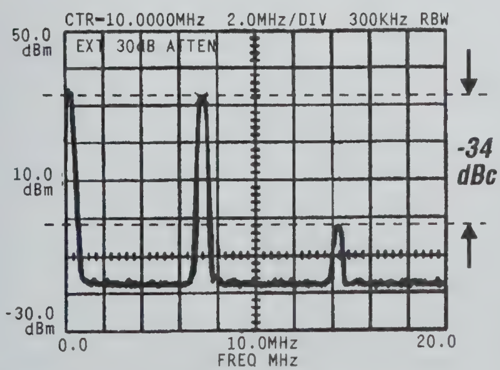
✔ Once you're on the air with the rig, you can trim up the setting of TC6 so that the receiver and transmitter are "dead on". The station you are listening to and your transmitted signal will be heard at the exact same pitch. Shown below is a diagram of a properly aligned rig, showing example Rx and Tx local oscillator frequencies and their relationship to each other and the crystal filter passband.

– K8IQY



RX and TX LO Alignment to the Crystal Filter Passband

2N2/40 on the Test Bench



The 2N2/40 Output Spectrum

The 7MHz fundamental and 2nd Harmonic power *after the output filters* (at the antenna terminal) are shown here. Compare with the spectrum on page 38 and notice how the second harmonic (14MHz) has been attenuated to 34dBc (34dB below the carrier) for FCC compliance. This is due to low-pass filters L6-L7 and C61-C65.

-NA5N

7. Bill of Materials (BOM)

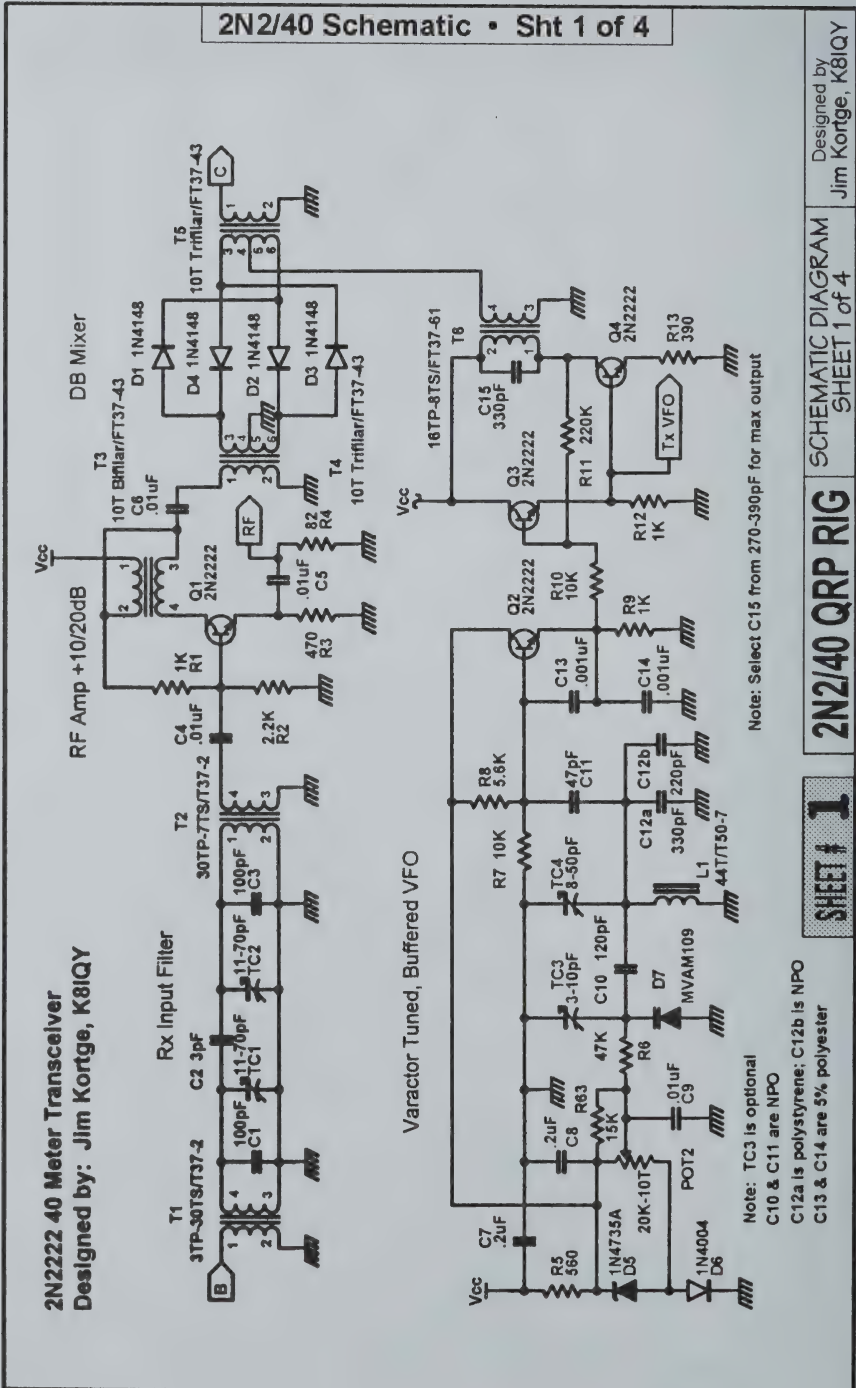
K8IQY 2N2/40 Parts List (Ver. 2.1) - Sheeet 1 of 2

ITEM	QTY	REF. DESIG./DESCRPTION	VALUE	MFR/PART NO.	✔
1	3	R56,R57,R58	2.2Ω		
2	1	R53 All Resistors	10Ω		
3	1	R65 5% 1/8W	12Ω		
4	1	R15 Carbon Film	27Ω		
5	1	R24	33Ω		
6	1	R65	47Ω		
7	2	R4,R54	82Ω		
8	2	R48,R55	100Ω		
9	1	R28	150Ω		
10	1	R17	270Ω		
11	2	R44,R64	330Ω		
12	1	R13	390Ω		
13	4	R3,R36,R38,R39	470Ω		
14	2	R5,R29	560Ω		
15	1	R23	680Ω		
16	6	R1,R9,R12,R22,R25,R45	1.0K		
17	1	R52	1.5K		
18	2	R2,R46	2.2K		
19	2	R40,R41	2.4K		
20	2	R59,R61	2.7K		
21	4	R14,R20,R30,R33	3.3K		
22	1	R62	4.7K		
23	1	R8	5.6K		
24	1	R51	6.8K		
25	7	R7,R10,R26,R42,R47, R49,R50	10K		
26	4	R27,R34,R43,R6	15K		
27	1	R32	27K		
28	2	R35,R37	39K		
29	4	R6,R16,R21,R31	47K		
30	3	R18,R19,R60	100K		
31	1	R11	220K		
32	1	POT4 (Trim Pot)	100Ω		
33	1	POT5	1.0K		
34	1	POT1	10K		
35	1	POT3 (Includes switch SW1)	10K		
36	1	POT2 (10 Turn)	20K		
37	1	C2 NPO	3pF		
38	3	C11,C46, or TC9 Alternate NPO	47pF		
39	6	C1,C3,C20,C21,C31, C45 NPO	100pF		
40	2	C10,C52 NPO	120pF		
41	2	C17,C22 NPO	150pF		
42	2	C32,C44 NPO	180pF		
43	2	C12B,C34 NPO	220pF		
44	1	C50 NPO	270pF		
45	1	C12a Polystyrene	330pF		
46	1	C15 NPO	330pF		
47	1	C61 Silver Mica	360pF		
48	1	C49 NPO	390pF		

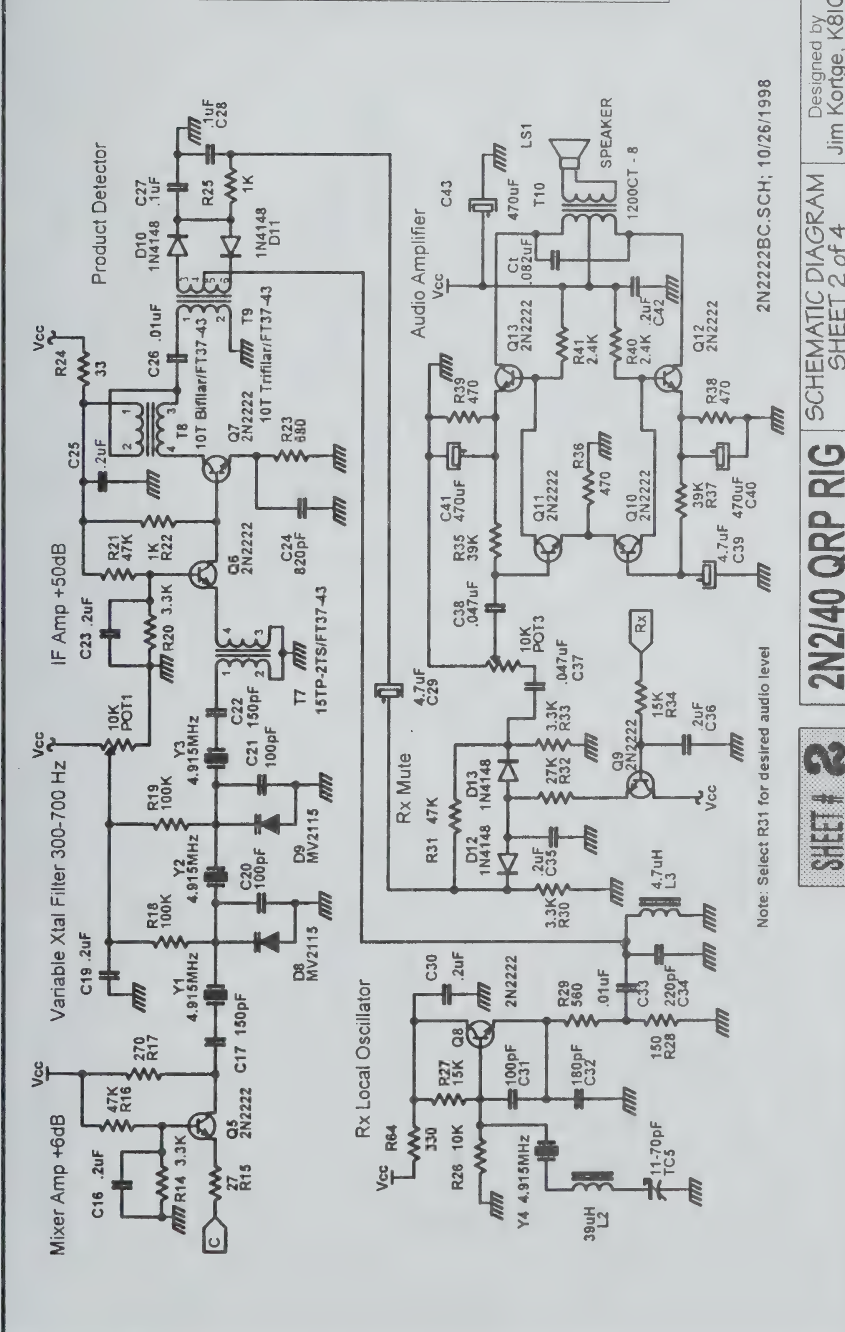
K8IQY 2N2/40 Parts List (Ver. 2.1) - Sheet 2 of 2

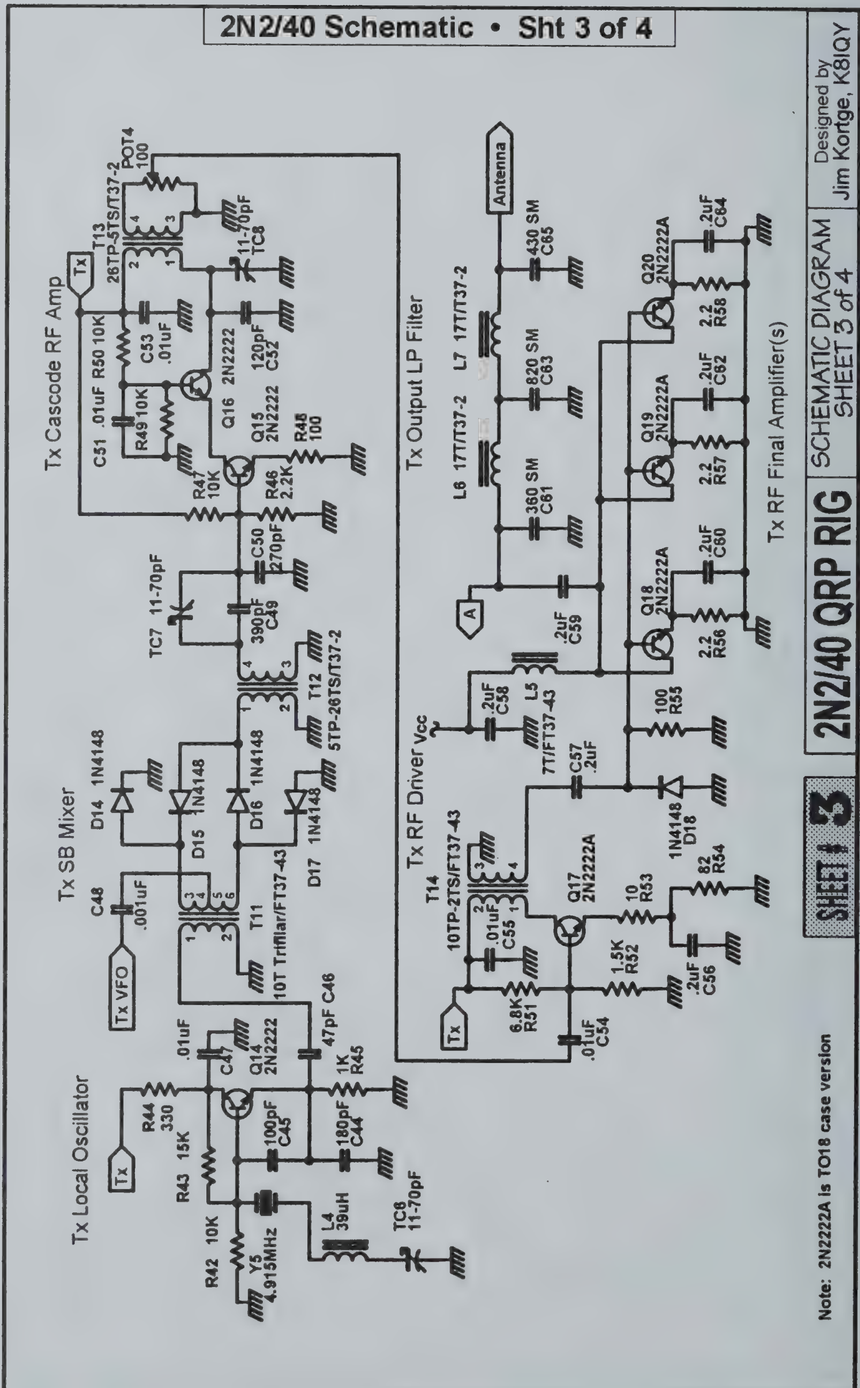
ITEM	QTY	REF. DESIG./DESCRPTION	VALUE	MFR/PART NO.	✔
49	1	C65 Silver Mica	430pF		
50	1	C24 NPO	820pF		
51	1	C63 Silver Mica	820pF		
52	2	C13,C14 5% Polyester			
53	1	C48	.001uF		
54	11	C4,C5,C6,C9,C26,C33, C47,C51,C53-C55,C68	.01uF		
55	2	C37,C38	.047uF		
56	1	Ct (Select to tune primary @ 750 Hz)	.082uF		
57	2	C27,C28	.1uF		
58	18	C7,C8,C16,C18,C19,C23 C25,C30,C35,C36,C42, C56-C60,C62,C64,C66	.2uF		
59	2	C29,C39,C67	4.7uF		
60	3	C40,C41,C43	470uF		
61	1	TC3 Trim Cap-optional	3-10pF		
62	1	TC4 Trim Cap	8-50pF		
63	6	TC1,TC2,TC5-TC8	11-70pF		
64	2	L2,L4 (Molded)	39uH		
65	1	L3 (Molded)	4.7uH		
66	1	L8 (Molded)	12uH		
67	6	L6,L7,T1,T2,T12,T13,	T37-2		
68	1	T6	FT37-61		
69	1	L1	T50-7		
70	9	L5,T3,T4,T5,T7,T8,T9 T11,T14	FT37-43		
71	1	T10 Audio Transformer 1200Ω CT:8Ω CT			
72	15	D1,D2,D3,D4,D10,D11, D12,D13,D14,D15,D16, D17,D18,D19,D20	1N914B or 1N4148B		
73	1	D5 6.2 volt Zener	1N4735A		
74	1	D6 Rectifier diode	1N4001		
75	1	D21 15 volt Zener	1N4744A		
76	1	D7 Varicap	MVAM109		
77	2	D8,D9 Varicap	MV2115		
78	5	Y1 thru Y5 (Match Y1-Y3 within 25 Hz)	4.915 MHz		
79	18	Q1-Q16,Q21,Q22 TO-39	2N2222A	Plastic	
80	4	Q17 thru Q20 TO-18	2N2222A	Metal	
81	1	LS1 8-ohm Speaker			
82	1	F1 Fuse	3AG 3A		
83	4	HS1 TO-18 Heatsink			
84	1	PC1 Power Connector			
85	1	J1 Stereo Jack	3.5mm		
86	1	J2 Mono Jack	3.5mm		
87	1	J3 Antenna Connector	BNC		
88	1	FH1 Fuse Holder			
89	1	SW2 Toggle Switch	SPST		

MFR/Part No. - Use to record exact manufacturer part number, or ordering part number/stock number from Mouser, DigiKey, Radio Shack, etc.
✔ - Use to indicate part on-hand, on-order, received, installed, etc.

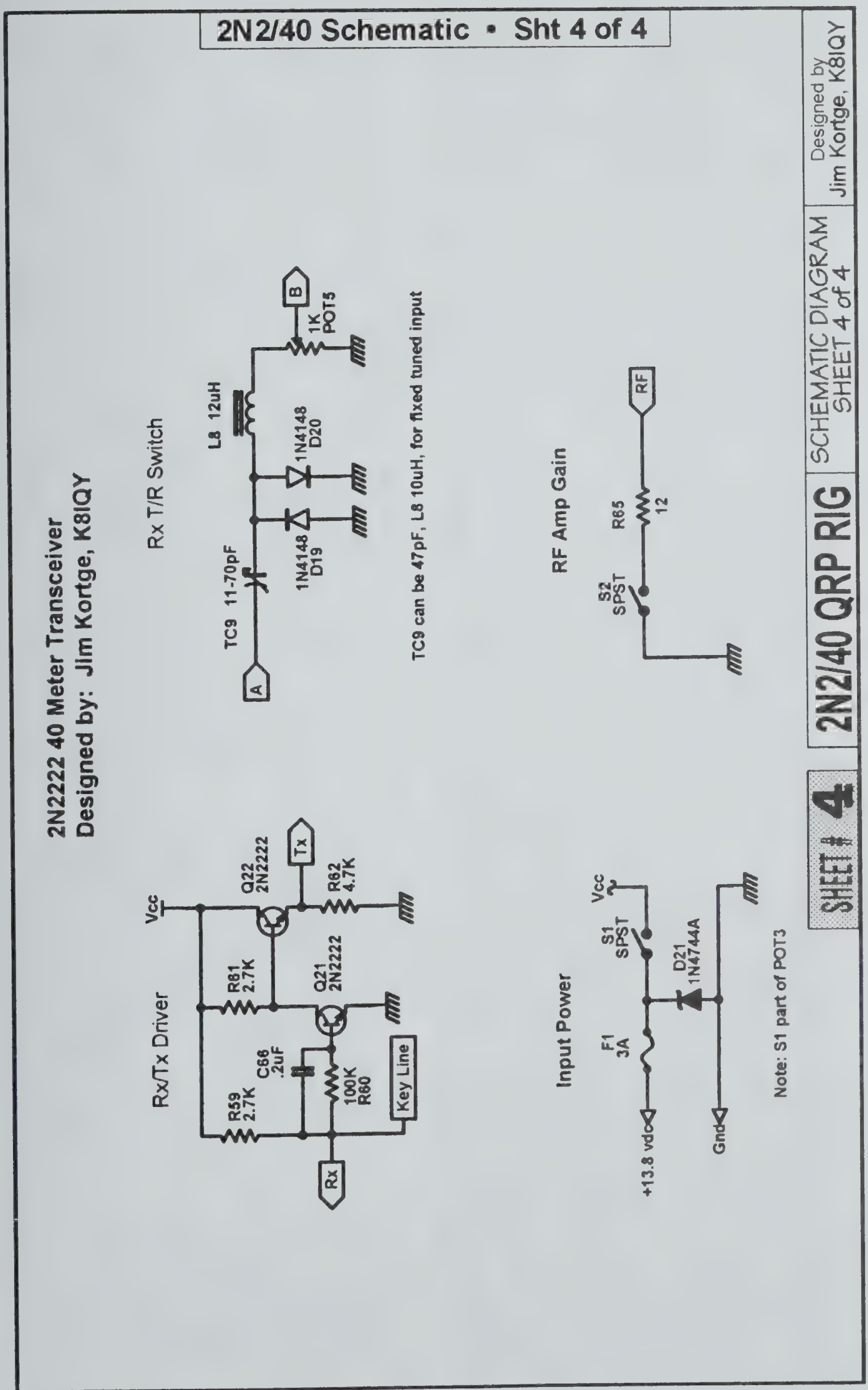

2N2/40 Schematic • Sht 1 of 4
2N2222 40 Meter Transceiver
Designed by: Jim Kortge, K8IQY
Rx Input Filter
RF Amp +10/20dB
DB Mixer
Varactor Tuned, Buffered VFO
T1 3TP-30TS/T37-2
C1 100pF
TC1 11-70pF
C2 3pF
TC2 11-70pF
C3 100pF
T2 30TP-7TS/T37-2
C4 .01uF
R2 2.2K
R1 1K
R3 470
Q1 2N2222
C5 .01uF
R4 82
C6 .01uF
T3 10T Bifilar/FT37-43
T4 10T Trifilar/FT37-43
D1 1N4148
D4 1N4148
D2 1N4148
D3 1N4148
T5 10T Trifilar/FT37-43
T6 16TP-8TS/FT37-61
C15 330pF
Q3 2N2222
R11 220K
Q4 2N2222
R13 390
R12 1K
Tx VFO
Q2 2N2222
R10 10K
R9 1K
C13 .001uF
C14 .001uF
R8 5.6K
C11 47pF
C12a 330pF
C12b 220pF
R7 10K
TC4 8-50pF
L1 44T/T50-7
TC3 3-10pF
C10 120pF
D7 MVAM109
R6 47K
R63 15K
C9 .01uF
C8 .2uF
C7 .2uF
POT2 20K-10T
R5 560
D5 1N4735A
D6 1N4004
Vcc
RF
B
C
Note: Select C15 from 270-390pF for max output
Note: TC3 is optional
C10 & C11 are NPO
C12a is polystyrene; C12b is NPO
C13 & C14 are 5% polyester
SHEET # 1
2N2/40 QRP RIG
SCHEMATIC DIAGRAM SHEET 1 of 4
Designed by Jim Kortge, K8IQY

2N2/40 Schematic • Sht 2 of 4





2N2/40 Schematic • Sht 3 of 4
Tx Local Oscillator
Tx SB Mixer
Tx Cascode RF Amp
Tx Output LP Filter
Tx RF Driver
Tx RF Final Amplifier(s)
2N2/40 QRP RIG
SCHEMATIC DIAGRAM
SHEET 3 of 4
Designed by
Jim Kortge, K8IQY
SHEET # 3
Note: 2N2222A is TO18 case version


2N2/40 Schematic • Sht 4 of 4
2N2222 40 Meter Transceiver
Designed by: Jim Kortge, K8IQY
Rx/Tx Driver
Vcc
R59 2.7K
C66 .2uF
100K R60
R61 2.7K
Q21 2N2222
Q22 2N2222
R62 4.7K
Tx
Rx
Key Line
Rx T/R Switch
A
TC9 11-70pF
1N4148 D19
1N4148 D20
L8 12uH
1K POT5
B
TC9 can be 47pF, L8 10uH, for fixed tuned input
Input Power
+13.8 vdc
Gnd
F1 3A
S1 SPST
Vcc
D21 1N4744A
Note: S1 part of POT3
RF Amp Gain
S2 SPST
R65 12
RF
SHEET # 4
2N2/40 QRP RIG
SCHEMATIC DIAGRAM
SHEET 4 of 4
Designed by
Jim Kortge, K8IQY

9. Miscellaneous Assembly Notes

This section will cover everything else that didn't fit under one of the previous categories. There are some general information items that are worth mentioning, which might make building a 2N2/40 a bit more successful.

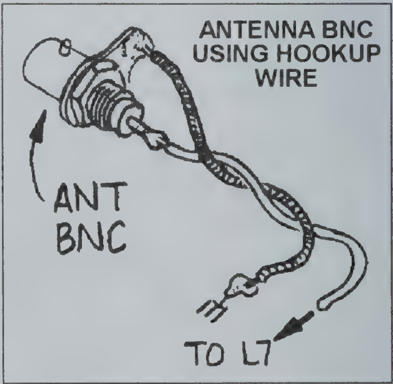
Interconnecting Wiring. If you look at the overall layout of the sections (see Interconnecting Wiring Diagram on page 14), it is apparent that there really are not very many wiring runs required. Standard hookup wire (and two short coax runs) are used throughout the 2N2/40.

Wiring. I used 22 gauge (AWG 22) stranded, Teflon coated hookup wire for this task. The Teflon wire is really nice because you can't melt the coating with normal soldering iron temperatures. This makes for better looking wiring, I think. Routing the wires between pads is more of following logic than anything else. I tried to add the "Vcc" wiring as the sections were built, so that it could be routed against the surface of the substrate. In some cases, it passes underneath the leg of a resistor or capacitor as an aid in keeping it tight to the surface (for example, see SEQ#5). The "Tx" and "signal" wiring was done in a similar manner. All external wiring to controls and connectors also use the AWG 22 hookup wire for the flexibity. Solid wire is not recommended for external wiring.

Coaxial Cable. The only two places that shielded signal wire was used were from the VFO to the Tx SBM ("W13" between SEQ#2 and #7) and from the i.f. amplifier to product detector transformer T9 ("W10" between SEQ#3 and #4). In these cases, a short length of RG-174 was prepared, with the shield grounded only at the VFO or i.f. amplifier end. The shield at the mixer and product detector ends were cut off, and the outside jacket pulled over the shield so that it could not make contact with the substrate surface. Doing the installation this way prevents having the shield grounded in two locations, which could cause a ground loop to exist.

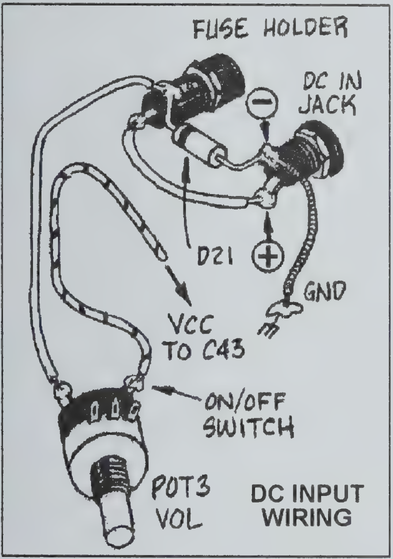
External Wiring. External wiring should also use *stranded* hookup wire for flexibility. Wiring to the potentiometers was done with flat, multiconductor cable, my favorite way to connect controls. If you haven't used this method, I encourage you to try it. You'll never go back to your old ways. You can buy 2 feet of 64 conductor, multicolored cable from many of the electronics suppliers for a couple of bucks, and that's enough wire for many, many rigs.

Antenna Jack. The lead from the "Antenna" pad to the coaxial connector (See SEQ#8) was so short in the prototype rig that I didn't bother with coax. A pair of 22 gauge wires was twisted together and used to make the connection.



However, the lead serving as the "shield" was terminated on the sub-board holding the PA transistors and output LP filter, and the BNC connector ground terminal. The total length of this run is about 1.5 inches.

DC (+12V Vcc) Wiring to the power connector was also done with leads twisted together. The Zener diode, D21, is just wired between the fuse holder "hot" lead and its ground terminal. Switch S1 is part of the audio control pot, POT3. By all means, make sure that you put in the fuse and the Zener diode. They will prevent smoking the rig if the power is hooked up backward, or if a power supply with an output higher than the Zener voltage (15 volts) is connected.



Lacing. After all of the wiring was done, it was secured at a number of locations with old fashioned, waxed nylon lacing cord to keep the wires together. (HINT: use dental floss if you don't have lacing cord). Tie wraps canSo also be used. This is one of those cosmetic items, and has no effect at all on the performance of the rig.

Soldering. A good soldering iron is a must. Mine is a 25-watt, temperature controlled unit, with a 1/8 inch chisel point. For normal soldering, I keep the tip temperature at 320 degrees C. When I am soldering a lead to the substrate, I raise the temperature to 350 degrees C, which gives a bit more heat capacity to melt and flow the solder. Two of the musts in doing this type of construction are to have some desoldering braid on hand and some pure rosin liquid flux. The soldering braid is used to wick up extra solder on a connection, or remove all of it, if a component gets installed incorrectly.

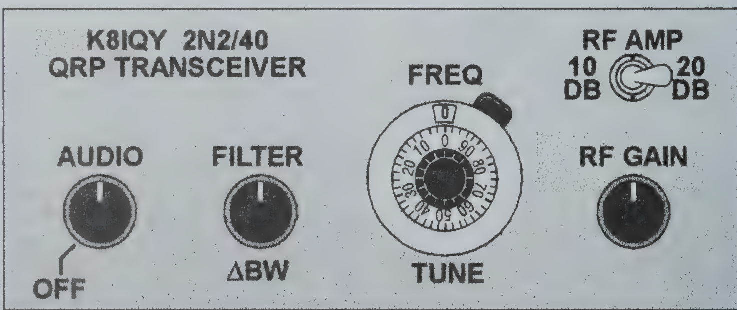
While all electronic grade solders contain flux, most have the minimum amount needed to properly "wet" a joint. A tiny amount of liquid flux can be brushed on a connection that appears to look overheated or "dry", and reheated to produce a superior solder joint.

Toroids. Winding toroidal inductors and transformers is explained on pages 8 and 9, and of course the details on the assembly drawings. Most people wind toroids without the use of any tools. The job is much easier if you use a small crochet hook. Each turn is wound by reaching through the center of the core with the crochet hook, and pulling the wire through the hole as the hook is retracted. Winding the core this way keeps the windings tight to the surface, and is much faster.

Use 26 or 28 gauge wire for all of the conventional transformers, but make sure there is a 20 to 30 degree gap remaining after all the windings are on a core. Transformer T14, and inductors L5 through L7 can be wound with a heavier gauge; number 24 is a good choice. All of the bifilar and trifilar transformers were wound using about 300 degrees of the core circumference. I use three strands of number 28 gauge, and twist them together at 6 to 8 turns per linear inch with an electric drill motor. Make a long piece (3 feet) of 3 strand, and another shorter piece (2 feet) of 2 strand, and then cut suitable lengths for winding each transformer.

The Enclosure. No rig is complete until it is installed in a case. For the 2N2/40 prototype, "home" became the inside of a TenTec TP-42 aluminum case. The case was painted flat black on all surfaces except the front and rear panels. These were painted light gray. A front panel overlay was drawn using COREL Draw. This overlay image was then reversed, and printed using a laser printer on a piece of transparency film. After trimming to size, the overlay was attached to the front panel with the printing on the inside, to keep it from being rubbed off. The control nuts from the various front panel controls hold it in place. If you build a 2N2/40 from this article, you will need to find a slightly larger case, as the TP-42 won't accommodate a 5X7 inch board. However, it appears a TenTec TP-46 or TP-47 case is the correct size case for the larger footprint. A custom case could also be built.

Front Panel. Here's what the front panel of the prototype rig looks like, which you can use for general control placement.



The 2N2/40 Front Panel Layout

10. ACKNOWLEDGEMENTS

Here is my chance to publicly thank all of the people that have helped along the way. There have been many, and they have helped immensely. First off is one of my heroes, Wayne Burdick, N6KR. It was Wayne who had the insight to propose the contest, and was the driving force behind keeping it pure. Many thanks to Bob Berlyn, N1PWU at HB Electronics, and their generosity in supplying ready-made 2N2222 semiconductor packages, at absolutely bargain basement prices. Their components are the heart of my original 2N2/40, and the second unit built for this article. Then comes Steve "Melt Solder" Weber, KD1JV. It was Steve who led the 2N2222 design charge, building the first working rig, and demonstrating to all of us that a viable design could be accomplished. Next comes Doug Hendricks, KI6DS, and his silent twin, Jim Cates, WA6GER. Without this "dynamic duo" there would be no NorCal, nor 2N2222 building contests, nor a long, admirable, legacy of great club kits. We are all indebted to these two fine gentlemen. Next on my heroes list is Paul Harden, NA5N. Paul was most helpful in putting the prototype through his "top 10 tests", to

The NorCal Resistor Kit

The NorCal Resistor Kit is just what you need to stuff out your parts bins and work bench with all the standard values needed for homebrewing and repair. All at a fraction of the cost of buying them separately. Ideal for about any QRP or homebrew project.

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1.0Ω	10Ω	100Ω	1.0K	10K	100K	1.0M
1.2	12	120	1.2K	12K	120K	1.2M
1.5	15	150	1.5K	15K	150K	1.5M
1.8	18	180	1.8K	18K	180K	1.8M
2.2	22	220	2.2K	22K	220K	2.2M
2.7	27	270	2.7K	27K	270K	2.7M
3.3	33	330	3.3K	33K	330K	3.3M
3.9	39	390	3.9K	39K	390K	3.9M
4.7	47	470	4.7K	47K	470K	4.7M
5.6	56	560	5.6K	56K	560K	
6.8	68	680	6.8K	68K	680K	
8.2	82	820	8.2K	82K	820K	

HINT: Cut out table for handy reference chart or use as parts drawer labels.

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Please make checks payable to Doug Hendricks (not NorCal).

verify that what I had observed qualitatively, was indeed based on quantitative performance measures. He alone is also responsible for all of the wonderful illustrations and pictures that are now a part of the 2N2/40 story. Without his help, this article would not have happened in the format you see it. And the last three that I'd like to thank are tall, skinny, Chuck Adams, K5FO, from big D, Preston Douglas, WJ2V, from the "big Apple", and another of my heroes, "Professor" Glen Leinweber, VE3DNL. It was Chuck (along with Doug H.) who provided much of the "push" to get the 2N2/40 project "out to the public", almost to the point of making me "go ballastic" with his timeline. He is a "let's do it" person. Preston Douglas' building a working 2N2/40 from an inaccurate set of schematics is almost an unbelievable feat. I had sent K5FO (and NA5N) an early set of schematics after Dayton, so he could see the general layout of the rig. While Preston was visiting Chuck, he also got a set. On his flight back to New York from Dallas, Preston decided that he was going to build the rig. To his credit, he did ask my permission and concurrence to proceed. Having him do that served two purposes: it gave me more confidence that the rig was reproducible, by hams who do not "bend wires or chase electrons" for a living; and we found one major and several minor, but none-the--less important, errors in the documentation. Kudos to Preston for his work. All but two of our communications took place via the internet, for those interested. And finally, Glen, VE3DNL for taking the time out of his busy fall schedule at the university to look over an early schematic and layout package. His observations always inspire me to "look out of the box" for unique solutions and better designs.

The very last person who needs to be thanked is here, all alone, because of her importance to me. That is my dear wife, soul mate, and lifelong friend, Kathy, KB8IMP. She has put up with untold hundreds of hours of my being squirreled away in the ham shack, working on the rig's design, building them, operating them, and putting the documentation together. Through it all she has been most patient, understanding, and supportive. Among her many areas of expertise is written English, and she contributed to this project by being my primary proof reader, and resident advocate for "getting the project done".

Summary - I indeed hope that this article has inspired you to get the parts and dive into scratch building a 2N2/40, or another design that you have fancied, but never built, using "Manhattan Style" construction methods. It is really a whole lot easier than it might appear at first blush. From personal experience, I can tell you that nothing you will ever build as a kit will compare to the satisfaction realized with doing a complete rig from scratch. If the dimensions of the layouts I provided look still look too small, build it on an even larger platform, maybe 6 X 8 inches, or even 7 X 9 inches. Or you could split it up into sections and build it that way, with the receiver on one board, the transmitter on another, and the VFO and Tx/Rx driver on a third, all appropriately wired together. I think the design is forgiving to the extent that it will work in almost any reasonable configuration. What I'm encouraging you to do is learn to build from scratch. It's fun, and a wonderful way to satisfy those creative desires. **Happy building!**

Building the Kortge 2N2/40 using "Paddyboard" or (Very) Ugly Construction Methods

By Preston Douglas WJ2V

This is a companion construction article to Jim Kortge's article and plans to build the 2N2/40 transceiver. A confession first. I came by these secret plans by illegitimate means. Last July I had to travel to Dallas for business, and spent some time with that gentleman QRPer, Chuck Adams, K5FO. He set aside almost a whole weekend of his valuable time for me, and we had a terrific time visiting the ham sites all over the metro Dallas region. Chuck had a preliminary set of drawings and schematics via Paul Harden for Jim Kortge's 2N2/40, and he kindly made me a set of copies. Chuck was enthusiastic about the design, but I didn't really have a chance to study the pages until I was on the plane headed home. Oh boy, this was some design. Despite the limitations of having only one kind of active device, this rig was very serious. It had a double balanced diode ring mixer, single balanced diode product detector, and smooth gain distribution. The filter was three 4.915 crystals; there were separate BFOs for the transmitter and receiver, so offset would be easy, and there was a serious effort at getting correct interstage impedances, accomplished mainly with lots of toroid transformers. It was designed for loudspeaker operation, with plenty of audio. The transmitter was also well thought out, with a neat, removable PA section so that at some future time the three 2N2222A parallel transistor array could be replaced by a "better" PA transistor. Plus, Paul Harden's drawings were brilliant. Unfortunately, only a few sections of the project were drawn up, so the thing couldn't be built until the rest was done and published.

Well, I couldn't wait. I had been reading Drew Diamond's book (sold by the G-QRP folks) about homemade projects using what he called "paddyboard" construction. Jim Kortge calls it "Manhattan" style; thus the original appellation of this project: The Manhattan Project. This is a system of "ugly" construction that uses little pads of PC board material, glued to a main "substrate" PC board. Each pad is an isolated island, making each one a soldering junction for several interconnected parts. Let me tell you, it works gangbusters. So, off I went with my unofficial copy of Jim's plans, to make a 2N2/40.

First, though, I did contact Jim, and Doug Hendricks, who was the inspiration and intended publisher of the 2N2/40 for their blessings. They thought it was a fine idea that I was going to try to build my own 2N2/40, and Doug even thought it would be great to publish a companion article to Jim's. This is it. Note, though, that my version of this system of building is just about as inelegant as Jim's design and construction patterns are elegant. If you build it my way, it will very likely work, but you certainly will want to build it into an opaque cabinet! Once it is surrounded by metal, no one will know you chose the ugliest method to build this terrific rig!

On homebrewing in general: I think you could probably build the 2N2/40 by just gluing the pads in accordance with Jim's or my patterns, solder on the parts, like laying carpet, and hope the rig works. But this is no kit, and you are going to be in for some hair pulling (assuming you have any left up there at your age) unless you have some test equipment. A scope is really helpful in some places to see where to set some of the trimmers, and you aren't going to know what went wrong without being able to follow signals through the stages, preferably as you build. That's just my opinion, and you may decide to build

the rig "blind" and have your local Elmer get it to work! I have photographed the building process and included some pictures here to illustrate. Notice that the receiver was built around the edges of the main PC board, from the rear left around to the front left.

I thought I would start with the VFO first. That is, after all, the heart of any rig, and I figured if that wouldn't work, then I ought to quit while I was ahead. The plan for the VFO is Fig 1. Notice the linear layout, which is the way I hoped to build the whole rig. Indeed, the pundits all say to try to build in line to reduce interstage coupling. Plus, you will have a much easier time keeping track of where you are, with less chance of "wiring" errors. And, the bonus is that you can keep track of progress by the length of the construction line!

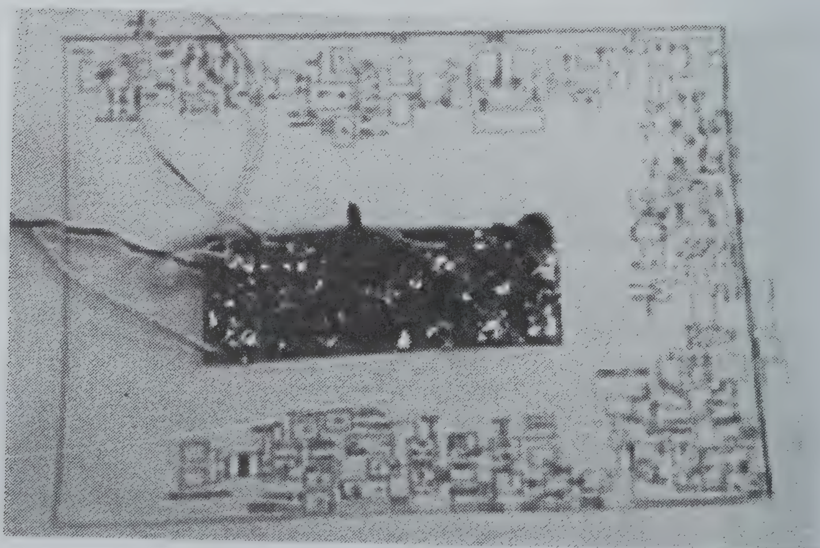
Since I really didn't trust myself to build a working rig this way, I decided early on in the planning stages that the pads would be big, ugly, and use plenty of room. I ordered a PC board that was 6 x 7 for this project, and though it still wasn't roomy, it gave me some space to work in. The pads were almost all squares or rectangles cut from scraps of PC material with a pair of tin snips. While others have suggested nibbling tools for making pads, my nibbler makes nibbles that are too small to be practical, and I wanted big pads anyway. Incidentally, the tin snips will occasionally bend up a piece, and these misshapen pads should be discarded if you are going to use super glue.

Crazy Glue brand super glue is terrific for attaching these pads to the substrate, but be careful. The glue is dangerous, poisonous, and hazardous to your eyes. Wear glasses, at least, and watch where you put your bare skinned hands with this stuff. You don't want to rub your eyes with super glue on your hands unless you like spending time in the ER. You can also glue your fingers together well enough to need to have them cut apart by a surgeon. No fooling. Keep the little ones (grandchildren etc.) well clear. Super glue will not fill gaps. It sticks well only when there are smooth, clean, fully contacted surfaces. Thus, the above-mentioned bent, twisted pads won't stick with super glue. Make sure to scrub the copper substrate with some Brillo and maybe alcohol too for gluing and electrical purposes. Of course, if you have unlimited time because you are already doing five to ten in Leavenworth (or was that Woolworth's?), then you can use epoxy and wait for it to harden with each pad.

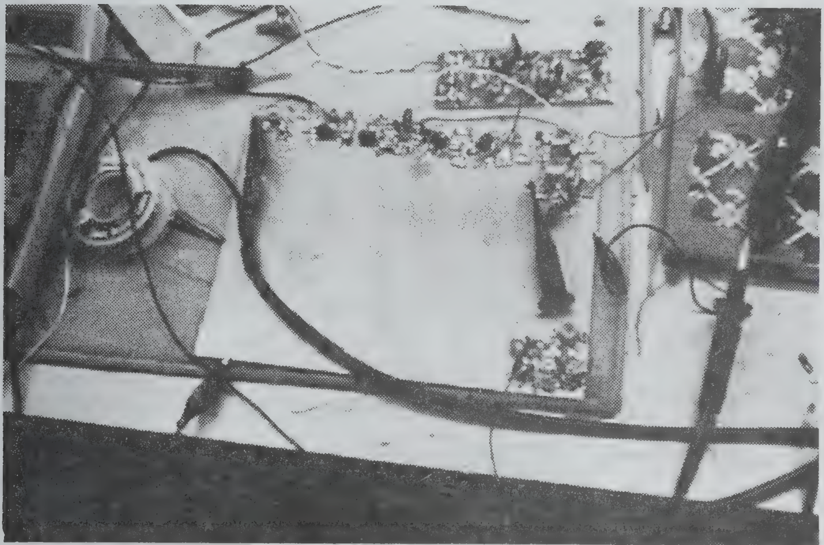
I started by sketching pad configurations for some of the stages. I drew the plans in modules, by hand, with a pencil; I could have built the rig from those hand drawings, but I couldn't get a handle on how big it would be, and whether the sections would fit on my PC board. So, I transferred all the drawings onto the computer. I don't have CAD; I find the Windows Paint program that comes with all versions of Windows is adequate for most drawing tasks. Thus, Fig. 1 and Fig. 2 were created. Actually, though, the building began even before the drawing was half finished. Incidentally, Fig. 3 is the PA and filter section; there are only three figures. You can make the whole rig from those three figures.

I suggest that if you are going to follow my drawings, you should start by building the VFO on a small rectangle of PC material, about 1" by 3-4". There are 15 pads and one little toroidal transformer to fit on this substrate board. You will want it to fit about where it is shown on Fig 1, so size your VFO strip accordingly. Note, that while there is some room to play with on a 6 x 7 board, you will want to leave yourself plenty of space by building the VFO reasonably small. Anyway, if you get

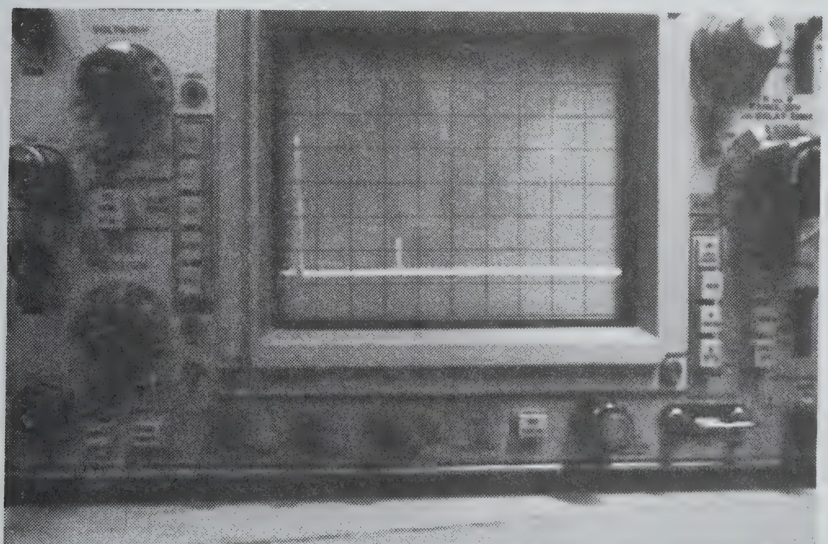
In background VFO board; in foreground is mainboard with front end at rear and RX LO near corner. Look at all that room to build!



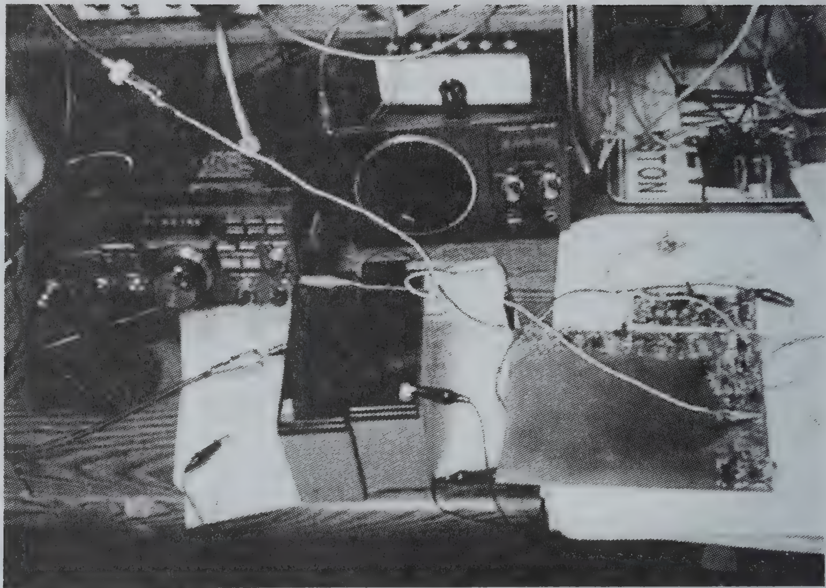
A look at the completed VFO board, sitting on a set of WJ2V plans showing the receiver layout for the mainboard.



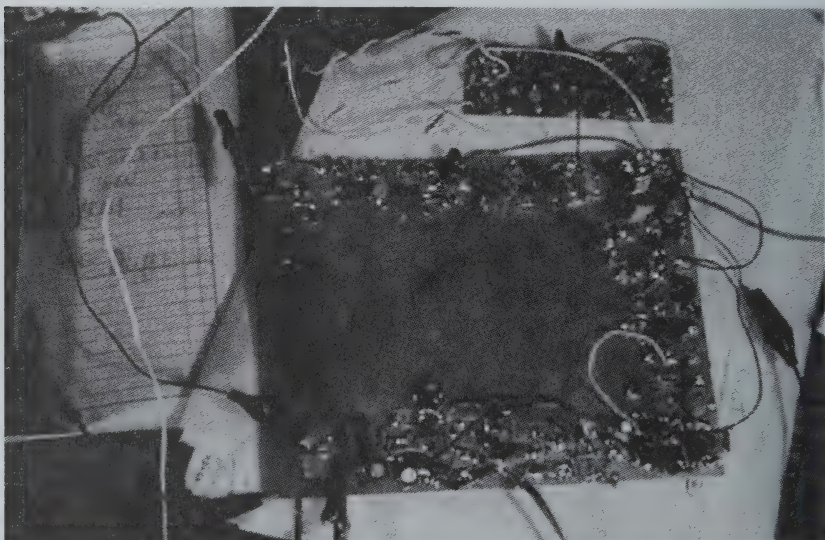
Here you see the front end, RF amp, mixer and post-mixer amp, built along the rear edge; turning the corner, the three xtal filter is built along the right edge.



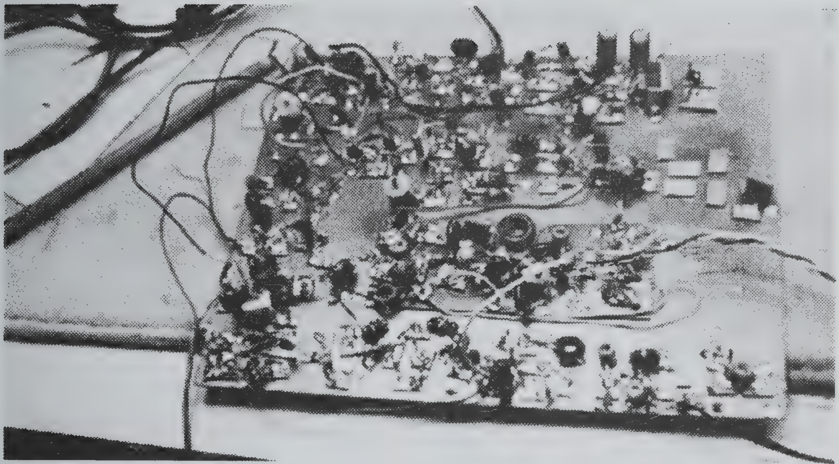
With the VFO powered up and connected to the mainboard double balanced mixer, and a 7 MHz signal injected at the front end...careful tuning of the VFO pot puts a 4.915 signal into the filter, and it appears at the output end of Y3 like magic on the Weber SA/SA MKII Spectrum Analyzer as a single clean signal. Wow, it works!



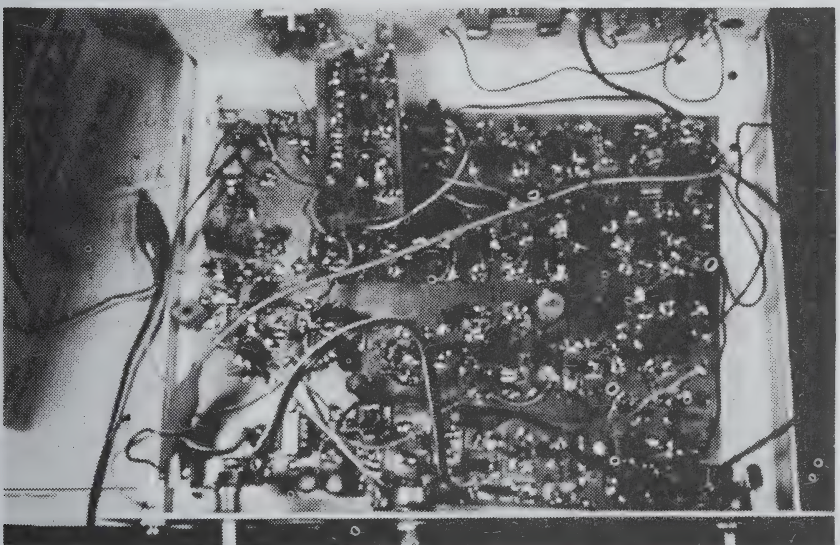
Here, a dipole was connected to the front end of the 2N2/40; taking the 4.915 amplified signal from the 2N2's IF amp stage (now built along the right edge-more progress), and using the Yaesu 757, tuned to 4.915 as a downconverter/product detector, I am hearing 40m signals through the RF and IF stages, as I tune the VFO. So far, so good!



The completed receiver. This shot shows the receiver actually receiving 40m signals on its own. The audio chain has been build along the front edge (foreground.)



Rx front end is in foreground now. VFO has been mounted to the mainboard with two bare, soldered wires at each end of the little VFO board. Next back towards the background is the incomplete transmitter chain. The T/R circuitry, TX LO, TX mixer are built. The pads for the cascode amp are in place, but not populated.



Rig is now completed. The AF circuitry is in front, the TX chain next behind. The TX is built in an "L" shape, the long end lying on its back, with the short end along the left edge. The "front end" of the receiver is along the rear edge. The VFO is seen under the PA board, which is hanging from a single solder lug attached to one of the antenna connector screws. Two contacts were made with the rig in this semifinished form in the QRP ARCI fall contest. The only alligator jumpers still in use here are to connect the keyer.

the VFO to work, you will know you have a fighting chance of making the whole rig work. If the VFO doesn't get off the ground, then perhaps the project should be re-evaluated.

Listen for the VFO on your station receiver and note that L1 may need a turn or two removed to get the oscillator into range. To tune 7000 to 7100, for instance, you would need the VFO to cover 2085 to 2185 kHz. You can increase the range of the VFO by increasing C10, but you may wish to consider that a limited VFO range (small C10) will allow adequate bandspread to eliminate the need for a ten turn pot which Jim specified in the design. By selecting a small C10, you can use a simple 20k pot and tune from say 7025-7055 easily. I found the C10 specified was somewhat small anyway.

You should have no trouble hearing this VFO on a general coverage receiver, as it is designed to drive a diode ring mixer, and these mixers require a healthy signal to drive them. Incidentally, for the double balanced mixer in the receiver, I was confused by the trifilar windings and Jim's compact layout. I redid the mixer layout to look like the textbooks, and changed to hot carrier diodes that are supplied by Dan's with his mixer kits. Three colored wires helped too. Together, these measures cured my unsatisfactory mixer results, but since I changed more than one factor at a time, I lost the chance to discover if 1N914 diodes would have done as well as the hot carriers, once correctly connected. So much for science. Trifilars are actually easy to wind. Take about 10" of three different colored wires, fix one end, and braid them like you would a kid's hair. I had no trouble fitting 10 turns of # 26 wire (less likely to break than # 28) on the 37 size cores.

Build, starting from the rear left corner, identified by the notation "to A". That first section is the protective front of the front end, and the RF input. Following that section, continue on into the double tuned front end. As you build each section, first you lay the pads in the pattern, then solder on the parts. It's just that easy. After you have built the first section, you can inject a 7 MHz signal and tune for max on you scope at C4 to see that the tuning works. Install the RF amp section and retune, if you have the equipment, for max signal at C6. Then build the mixer, the post-mixer amp and the filter, around the corner. Now, you should be able to tell if you are going to have a working rig. Connect up your VFO, inject a 7 MHz signal at point A, and look for it to squeak through the mixer at outer end of Y3. If you get this far, congratulations, it looks like you are going to make it all work.

Continue laying pads and filling them with parts for the IF amp. You can connect the IF amp at C26 to your general coverage receiver tuned to 4.915 MHz, to see if, by using your station receiver as a second IF and product detector you have most of the receiver running. You should be able to hear on the air signals this way. The product detector follows along the right side, and note that the corner area circled denotes the RX local oscillator. You might consider building that RX LO earlier (out of sequence), in case you need to test the IF filter-it makes a perfect test oscillator, and you can see it sweep through the filter with a scope or spectrum analyzer, if you need to.

Now, for the home stretch, turn the PC board around 180 degrees and build the AF section across the front as shown. You may just be astounded when you connect a speaker to the pads at the end of the chain, when the radio plays. An antenna at "A" ,VCC all around, and a little tuning should result in 40m CW playing its music. Note, too, that you will need to temporarily tack a 2.7 meg resistor from the point

labeled "RX" to VCC to bring the AF section to life. This is replaced by the T/R circuitry in the other bordered area when the transmitter is built.

On to the transmitter. Note that the backbone of the transmitter is constructed inside and parallel to the AF section of the receiver, turning the corner and ending on the left edge of the board at the words, "To PA". First, the little T/R system is built, and you can test it for switching function. To do that, just try grounding the RX pad, and see that the TX pad goes to about 11 volts. Then the TX LO, the mixer, and the amps. At the end of the chain, you have a transceiver. Of course, without the PA, it isn't going to get you very far yet. Still, you should be able to hear sigs, see that the T/R works, and hear the transmitter! At the point you have the mixer done, connect the VFO into its insertion point and see that you are able to send a signal to your main station receiver by keying the RX line to ground. Keep going with the transmitter, until you reach the PA.

I had a bit of trouble with the Cascode amplifier. The transmitter chain depends on tuned circuits that must be resonant, else the signal getting through will be too feeble to drive the finals. I don't know if my primary of T13 had too few turns or not, but I had to add an additional cap across TC8 to get it to percolate at 7 MHz. Of course, the scope helped immensely here, and the spectrum analyzer gave me some hints too. I even tried dipping T13 in situ with my grid dip oscillator, and indeed it seemed to dip way up in the 8 MHz range until I added that extra cap in. This is the kind of problem that a homebrewer may face, and have to solve to get the rig to fly. Once you can see about 3 v p-p at the output side of C57, you know you have succeeded. You can then go on and build the PA and output filter circuitry on it own little board, and you are nearly done.

The PA and output filter are constructed on a separate strip of (double sided) PC board material, like the VFO, per Fig. 3. This module is mounted on a standoff, above the main PC. I stole an idea from one of Paul's illustrations and hung the whole PA board from a solder lug with one of the screws that holds the UHF antenna connector on the back panel.

I assume Jim will detail tune up of the receiver and netting of the transmitter. Here's a simple version. First, adjust TC5 in the RX LO until you hear the "rushing sound" that the late Roy Gregson described in his tune up instructions for his kits. This is the "live" sound you hear when the LO is mixing with the IF to allow you to hear backwards into the filter, kind of like getting the pipe lined up so you can hear the far end. Then, using an on air signal or injected one, peak TC1 and TC2 and TC9 for maximum volume. Now, get the signal centered by adjusting your VFO for loudness in the speaker (or, better still, tune for max with the scope on the output side of the filter at Y3-this is better because the human ear isn't sensitive enough and can be fooled into "hearing" changes in volume when it hears a change in pitch.) Now, adjust the RX LO trimmer, TC5 for a 700 Hz tone. That's it, the receiver is tuned.

Now, use a local signal in the shack and tune it in with your main receiver and the 2N2/40. Get the pitch of this local signal the same in both receivers. Now shut off the local signal, key the 2N2/40, and tune TC6 to get the same pitch on the station receiver. Your offset is now right. Key the transmitter and adjust Pot 4 for less than 1 watt-into a 50 ohm dummy load, please! Adjust TC 7 and TC 8 for max, and if you have a scope, adjust for cleanest signal. Keep an eye out for overheating of the PA transistors, and limit key down time. Once TC7 and TC8 are maxed, reset Pot 4 for about 1.5 watts out. I set my output

for 1.25 watts, just to be on the safe side and assure longevity of the PA transistors.

I leave the cabinetry details, the fuse circuitry (a slow-blow fuse is recommended), and switch wiring to you. If you can build the rig to this point, these tasks should be trivial to you. Enjoy this great rig. 72, Preston **Note: The layout files in color are on the NorCal Webpage: http://www.fix.net/norcal.html**

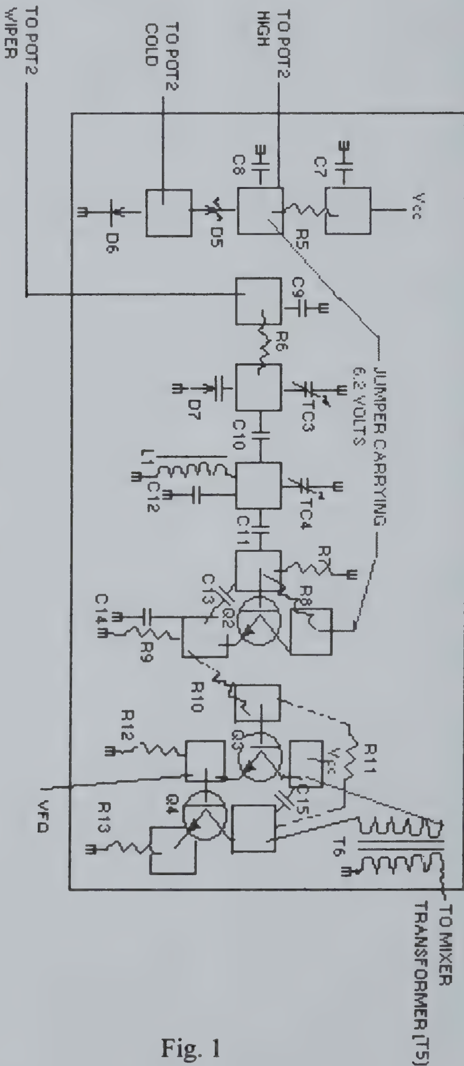


Fig. 1

FIG 3A

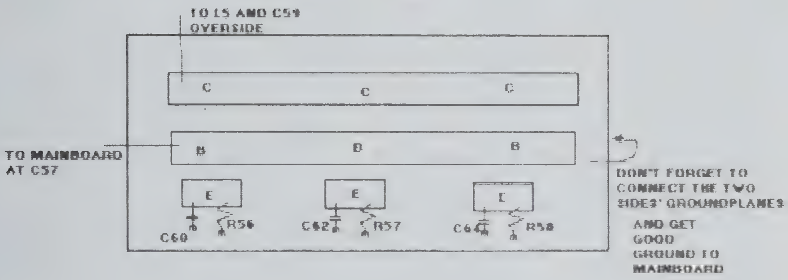
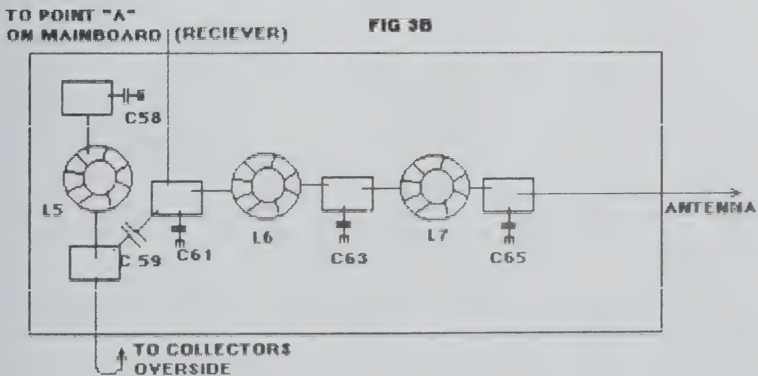
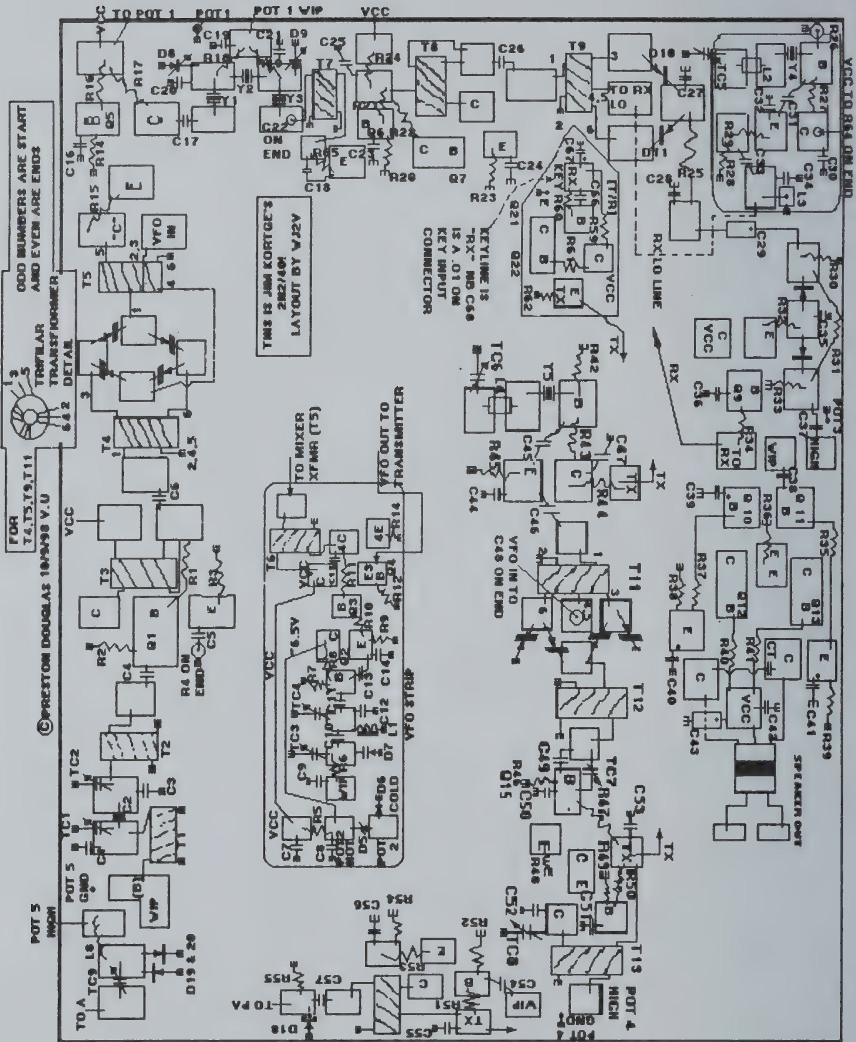

TO L5 AND C59
OVERSIDE
C
C
C
TO MAINBOARD
AT C57
B
B
B
DON'T FORGET TO
CONNECT THE TWO
SIDES' GROUNDPLANES
AND GET
GOOD
GROUND TO
MAINBOARD
E
E
E
C60
R56
C62
R57
C64
R58

FIG 3B


TO POINT "A"
ON MAINBOARD
(RECIEVER)
C58
L5
C 59
C61
L6
C63
L7
C65
ANTENNA
TO COLLECTORS
OVERSIDE



Preston Douglas WJ2V's Layout of the 2N2/40

1998 QRP "Run to the Borders" to the Field Contest Results

by Joe Gervais, AB7TT
vole@primenet.com

Here are the results of the 1998 QRP To The Field "Run To The Borders" Field Day. You folks were GREAT! Couldn't believe how many triple-border points there were! Had to double-check the atlas a few times to make sure you weren't pulling my leg.

We were absolutely amazed at the great lengths many of you went to in order to get to your border sites. Hats off to you! And to those who got on the air from the homestead for a brief hour or so to give the Field Ops some QSOs, every Field Op owes you a beer. Or in my case, Barq's rootbeer or JoltCola....

95 logs were sent in - YOWZA! It's always great to read the comments you guys write. Helps make the long nights at the keyboard go faster. Thanks!

Some awesome scores, some VERY close calls, and a whole lot of fun. For a few folks this was their first contest ever, always nice to see you joining in the party! And whether you bagged 200+ QSOs or 2, you got on the air and proved that QRP not only works, it's also the best game in town.

Three Muli-Op stations (N0UR, N4ROA, W5ON) were neck-and-neck for 1st Place in their category. Team N0UR just BARELY beat out Team N4ROA by a mere 5,000+ points out of nearly 600,000 - less than 1%.

Roger (N7KT) took a solid 1st Place in the Single Op category, with his Four Corners x4 multi proving to be the clinching factor. Well done!

A total of 33 Field Ops ran for the borders.

Well over 95 QRPers had a great time! Thanks again to all for your support. Cheers de AB7TT, Joe, NorCal Contest Manager

——————— QRPTTF '98 RESULTS ———————

NOTES: A (*) by the callsign means multi-op. For location, H=home, F= field, FB = Field (Border), and M = mobile.

Callsign	Loc	Borders	Q's	SPC	Power	Score
N0UR(*)	FB	ND/SD/MN	146	67	5W	586,920
N4ROA(*)	FB	VA/TN/NC	167	58	4W	581,160
W5ON (*)	FB	AR/MO	173	76	5W	525,920
N7KT	FB	AZ/NM/UT/CO	81	47	4W	304,560
W5NC(*)	F	-	204	57	5W	232,560
WA7LNW	FB	UT/AZ	123	43	5W	211,560
KI0II	FB	WY/NE/CO	84	40	5W	201,600
N7CEE (*)	FB	AZ/NV/UT	88	38	5W	200,640
WU0L	F	-	163	61	5W	198,860
KW5OK	FB	MO/OK/KS	66	41	5W	162,360

W4ED	FB	GA/TN/NC	67	38	5W	152,760
W0CQC (*)	F	-	143	51	5W	145,860
AA7QU	F	-	140	49	5W	137,200
W0CH	FB	MO/KS/OK	55	39	5W	128,700
N4EO	F	-	109	45	5W	98,100
KD7S	F	-	119	39	5W	92,820
K9TSM(*)	FB	IN/MI/OH	45	34	3W	91,800
NQ2RP	F	-	91	50	5W	91,000
K0BC (*)	FB	AR/MO/OK	56	27	5W	90,720
KD7AEE	H	-	145	61	5W	88,450
K4JSI	FB	DE/MD/PA	45	31	5W	83,700
N6WG (*)	F	-	116	36	1W	83,520
K7NX (*)	FB	AZ/NM/Mex	46	30	5W	82,800
W4DEC	H	-	142	58	5W	82,360
WQ3RP (*)	FB	MD/VA/WV	34	26	5W	78,000
KG5N	F	-	94	39	3W	73,320
W5VBO	H	-	125	56	5W	70,000
WA1QVM	FB	MA/RI	54	32	4W	69,120
K5OI	FB	NM/TX/Mex	47	24	5W	67,680
AC6NT	FB	NV/CA/AZ	103	32	5W	65,920
AC6KW	F	-	88	37	5W	65,120
W5GIX (*)	FB	LA/MS	49	31	5W	60,760
W6RA	FB	CA/OR	63	23	3W	57,960
KG0MZ (*)	FB	KS/MO	44	31	5W	54,560
VE6DN (*)	F	-	85	31	5W	52,700
W3BTN (*)	F	-	77	33	5W	50,820
K8CV	H	-	103	46	5W	48,410
N9ZXL	FB	IL/WI	38	22	5W	48,400
WQ2RP (*)	F	-	79	29	5W	45,820
N7KE (*)	F	-	74	30	5W	44,400
W0YSE	FB	UT/WY	44	25	4W	44,000
W0QF	FB	SD/ND/MN	38	17	1W	38,760
K6ZNI	F	-	56	32	5W	35,840
WA2IPZ	FB	ID/UT/NV	32	18	4W	34,560
AA7MU	FB	UT/WY	52	31	4W	32,240
AE4GX (*)	FB	GA/SC/NC	21	24	5W	30,240
WE6W H	-		91	33	5W	30,030
KN1H	FB	NH/VT	32	23	900mW	29,440

N2TO	F	-	38	28	5W	28,112
N4KN	F	-	48	29	4W	27,840
AB5UA	F	-	43	23	5W	24,840
VE3ELA	F	-	41	29	3W	23,780
NQ7X	H	-	66	32	5W	21,120
KI6DS	FB	NM/TX/XE	29	12	5W	20,880
WA6FUH	F	-	30	23	5W	20,240
N0IBT	F	-	32	29	4W	18,560
CO4BM	H	-	68	27	5W	18,360
W0RSP	H	-	33	26	950mW	17,160
N7GS	FB	MT/WY	28	15	1.5W	16,800
AB7TT/flu	H	-	56	27	5W	15,120
WA8RXI	H	-	78	36	4W	14,040
AE6TT (*)	F	-	50	14	5W	14,000
WD7Y	H	-	72	19	5W	13,680
KS4V	F	-	40	16	2W	12,800
K4KJP	H	-	44	28	2W	12,320
NR3E	H	-	36	25	5W	9,000
K5RAC (*)	F	-	36	27	5W	8,640
N9UKX	H	-	37	23	5W	8,510
K0SU	F	-	22	20	5W	8,400
W8TM	H	-	39	21	4W	8,190
WA9WAC (*)	F	-	40	9	1W	7,200
W8TIM	H	-	34	16	2.5W	5,440
WA9PWP	M/H	-	32	17	5W	5,440
K2HPV	F	-	18	13	2W	4,680
W6ZH	H	-	23	20	5W	4,600
KD6JUI	F	-	18	12	5W	4,320
VE5RC	H	-	23	18	5W	4,140
KA1AXY	FB	MA/CT/RI	10	6	2W	3,600
N0QT	F	-	20	9	5W	3,600
AH7R	F	-	16	11	5W	3,520
KE6QMX	F	-	22	8	5W	3,520
WA8GHZ/5	M/H	-	18	12	5W	2,880
KC8JIE	H	-	18	14	5W	2,570
KB2VTN	FB	NY/NJ	14	11	5W	2,340
KU7Y	H	-	20	10	200mW	2,000
AB0AE	H	-	16	12	5W	1,920

KQ0I	H	-	14	13	5W	1,820
KK7HV	F	-	11	6	5W	1,320
N4UY	F	-	7	8	2W	1,120
W8LN	FB	AL/TN	5	5	5W	1,000
WA1OFT	H	-	13	12	5W	780
KB0VCC	F	-	6	5	5W	600
K2UD	H	-	6	5	2W	300
N7DW	F	-	3	3	5W	180
WD8MNV/6	H	-	3	2	5W	60
K8NI/flu	H	-	3	3	4W	45
K3TKS	H	-	2	2	5W	40
AF9J	H	-	3	2	4W	30

QRPTTF '98 Soapbox

(AB7TT Note: Thanks to all for the kind comments and encouragement! Makes the log processing much nicer!)

"This was my first contest ever on CW. It was a thriller. ... I was blocked by snowdrifts from reaching the CO/UT/WY state corners, so had to settle for UT/WY. I set up in semi-blizzard squall condx Friday night ... Had lots of fun and no company other than my dog, herds of elk and antelope, and a few yacking coyotes." - Lowell, AA7MU (AB7TT Note: Wow!)

"Everyone one of our group ... had a turn at operating, and afterward a tube steak and barby hamburger turned out by the XYL for lunch plus a dessert of donuts and cookies, followed by more coffee! ... Regardless of how we make out in the scoring, we all agreed that it was a great get-together and the day will be remembered for a long time." - John, VE6ZAA and the rest of the Calgary QRP Group.

"In spite of poor band condx, it was a lot of fun and I hope the format will be repeated next year!" - Mal, N7GS

"Had a great time handing out border QSO's - can't wait 'til next year's QRPTTF." - Joel, WA1QVM

"I had a fine time. I never heard any CW above 25 wpm. A nice friendly contest. ... If I'd known my XYL was going to be at a convention that day, I would've been in the field. Thanks for the event and I hope to work it next year." - Ed, WD7Y

"Called CQ on 10m, but no response. Didn't even bother with 80m. ... 15m was a surprise - along with KI0II for a triple, worked AH7R off the back of the beam! Good fun - hope that I can spend more time with this next QRPTTF." - Pete, W6ZH

"QRPTTF was scheduled for the opening day of trout season. ... I set up my little backpacker inverted-V on a ridge overlooking the river. 2,000 ft. below, drift boats were sliding by, each with 2 or 3 happy fisherman. Rats! But as the day unfolded ... calling CQ that morning began to feel like dropping a nice cast, right over by that promising riffle. Searching and pouncing was, I realized, the human analog of what trout do." - Russ, AA7QU (AB7TT. Note: Wow! Zen and the art of QRP fishing!

"I was running 2W from my unmodified HW-7. ... The guys I worked were real heroes for sending repeats my way ... It was completely deaf, having blown a front-end dual-gate MOSFET ... Oh well, I enjoy the minimalist approach (I also enjoy visits to the dentist)."- Howard, K2UD (AB7TT Note: There's a bit of masochism in all

QRPers!)

"Had mucho fun despite lousy condx ... Tnx for the contest!"- Dave, NR3E

"Had a great time, what a fun theme for a QTTF! Can't wait to find out what you'll come up with for next year." - John, KN1H (AB7TT Note: Surprise! If it's still fun, don't fix it! :-))

"First contact was Russ AA7QU (unlike his backpack camping I had hot and cold running water, propane stove and heat, and was out of the wind inside the camper). Things I learned ... Don't eat a big lunch during contest as no QSOs were logged during nap." - Charlie, WA2IPZ

"What a great contest! Here are my claimed scores ... Just think what this would have been if I'd just headed for the border (not Taco Bell)!" - Nick, KG5N

"Had to travel out of town for a club meeting, but still tried to get on for last half hour of the 'test to give out some QSOs." - Eric, AF9J

"I had KK5XO as a guest, was his first contest. Fun to watch him! The temp hit 90F and 40mph winds. Took lots of breaks. Did I mention the wind? " - Clif, AB5UA

"I did not even plan on entering, but since I was driving around and heard some QRP stations, well, I couldn't resist!" - Paul, WA9PWP/M

"Just 20 miles south of my very own front door is the BLM fence line that separates UT and AZ ... beautiful day and location for operating ... connected the ground radial system to the UT/AZ border fence, which I believe is a rather unique competitive advantage!" - Jack, WA7LNW

"We operated on an undeveloped park on the border between crazy and stupid. Had a lot of fun doing it and introduced a few people to QRP." - W5NC, Multi-Op (lots of ops).

"Our station was set up near ... where AR/MO/OK meet. This was the first QRP event for some of us and we really enjoyed this very much!" - Gary, K0BC

"I was very ill April 25th, but wanted to see what QRP sigs looked like so I dragged myself out of bed for about 10 minutes. Sigs were very good and I quickly worked 3 QSOs."- Norm, K8NI (AB7TT Note: Seems we had the same flu that day!)

"We operated from just after 9:00am until the wind blew over out operating tent ... it was strong enough that I could no longer hear stations with the earphones. Bill's two boys flew kites, until those were also dashed to pieces." - Lloyd, K7NX (AB7TT Note: Wow! Sure you weren't set up at Riley, NM?!?)

"Great contest - lots of fun - on the border of insanity I am sure. Two years I have been in the mountains for this and got snowed on. One year I was snowed in at the house. We gotta make this "Spring" thing later!" - Rick, K0SU

"This was a great event, a lot of fun. The Baton Rouge ARC operated as a club event. It was the first time some of the guys had ever operated QRP. Looks like it may not be their last. They all said we should make the NorCal TTF an annual event for us." - Tom, AC5JH (EAB7TT Note: Great!)

"QRP interest must be growing in leaps and bounds, judging from the congestion around 7.040. 40m didn't seem too good, but enjoyed the contest anyway." - Doug, W8TIM

"Sure enjoyed the contest. Took the gear and sat up on the IL/WI state line north of Durand, IL. Watched the farmers plant corn while I played radio! It was fun and enjoyable for my first TTF contest." - Dave, N9ZXL

"I had a great time. 20m was fading throughout the contest, so we worked QRP to QRP on propagation peaks - a greak skills enhancement exercise!" - Terry, K4KJP

The 5th Annual ... **QRP TO THE FIELD '99**

Run to the BORDER Part II

Sponsored by NorCal

Saturday, April 24, 1999
1600-2400UTC

Categories: Field, Home, DX, Taco Bell (see below) and multi-op
Exchange: RST and SPC (**S**tate/**P**rovince/**C**ountry)
Border stations send SPC's their border location sits on.
Example: "599 AZ/CA/NV" for a border station
QSO Points:
†Each domestic U.S. QSO -- 5 points
†Each DX QSO (incl. VE, HI, AK) -- 10 points
†Border ops count as one QSO for each SPC they send.
Example: "599 AZ/CA/NV" is 3 QSO's for 15 QSO points.
Multipliers:
x4 **Field** Location (battery power, temporary antennas)
x2 **Home** location (commercial power, fixed antennas)
x2 **DX stations** outside the contiguous U.S., including VE,HI,AK
Border stations: xK, where K=number of SPC's in exchange
Example: "599 AZ/CA/NV" K=3 (and your x4 field location!)
x**SPCs** for each band. (10 SPC's on 20M + 8 on 40M = 18 SPCs)
FINAL SCORE: Add QSO points. Apply multipliers listed above.

† Same station may be worked on more than one band for QSO points and SPC credit for each band.

Special TACO BELL Border: You will be allowed a 2-state "border" if you operate from near a TACO BELL restaurant. To qualify for this x2 multiplier, you must submit a photo with your log that shows **both** your station and the Taco Bell. Thus, you need not operate from the parking lot, but close enough to be in the "field of view" of the photo. Each Taco Bell has a store number. You must record the store number on your entry/summary sheet.
Exchange: Your state/Taco Bell
Example: "NY/TACO BELL" or "NY/TACO" (not "TB")
If you work a Taco Bell station, it is worth 2 QSO's (10 points).

KI6DS being frisked at the Mexican border during the 1998 QRPTTF "flagship" station

The Fine Print ...

- Logs must include the station location and description (rig, antenna and power). Logs without this information will be considered check logs.
- **Deadline** is **June 1, 1999.**
- All contest decisions are final.
- Results will be published in QRPp, and posted to QRP-L
- For rule clarification contact NA5N at pharden@nrao.edu

Send logs to:
Joe Gervais, AB7TT
QRPTTF Contest Manager
P.O. Box 322
Peoria, AZ 83580-0322
email: vole@primenet.com

How close must I be to the border?
Use common sense - get as close as feasible to the border without risking your welfare or safety. For borders running through bodies of water, operate from either shore. QRPTTF, like all contests, is on the honor system. The object is to have fun, both on-the-air and off. So get some QRPers together and HAVE FUN!

NorCal's T-Shirts

NorCal offers two shirts:The NorCal T-Shirt and The NorCal Zombie T-Shirt (Limited Edition) The price is $15 each plus $3 shipping and handling in the US, $5 shipping for DX. The shirts are the recognizable NorCal "GOLD" and high quality and heavy duty. The NorCal shirt is imprinted with the NorCal logo and the NorCal Zombie shirt is imprinted with the NorCal Zombie 'Toon. The shirts are gold with the NorCal Logos in black and the Zombie 'Toon is multicolor. To order Send $15 + $3 postage ($5 DX) to: Jerry Parker,
426 Tanglewood Ct.
Paso Robles, CA 93446

Don't forget to specify your size: M, L, XL, XXL (Note XXL shirts are $3 additional) Please make check or money order out to Jerry Parker, NOT NORCAL, US Funds Only.

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Shipping: US

$4 for 1 - 3 issues, $5 for 4 - 6 issues.

Shipping: Canada

$4 for 1 issue, $5 for 2 - 3 issues, $7 for 4 -6 issues.

Shipping: DX Europe & South America

$5 for 1 issue, $7 for 2 - 3 issues, $10 for 4 - 6 issues

Shipping: DX Pacific Rim, Australia & New Zealand

$5 for per issue ordered.

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QRP Frequency Crystals

NorCal has available the following crystals in HC49U cases for $3 each postage paid in th e following frequencies: 7.040 MHz, 7.122 MHz., 10.116 MHz. Send your order and payment in US Funds only to: Doug Hendricks , 862 Frank Ave. , Dos Palos, CA 93620, USA. Make check or money order to Doug Hendricks, NOT NorCal.

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